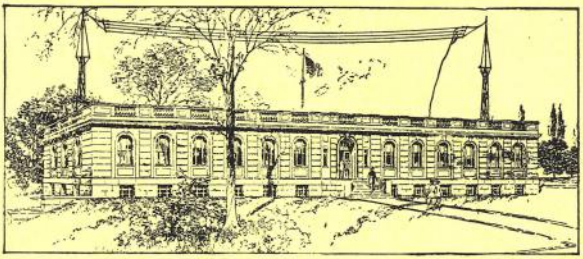
RADIO HANDBOOK

LEFAX

LEFAX RADIO HANDBOOK

THE REAL AUTHORITY ON ALL RADIO SUBJECTS—IN EVERYDAY LANGUAGE—BY THE HIGHEST GOVERNMENT EXPERTS—NOT OPINIONS—NOT HEARSAY—BUT TRIED AND TESTED FACTS



NEW RADIO LABORATORY OF THE U. S. BUREAU OF STANDARDS

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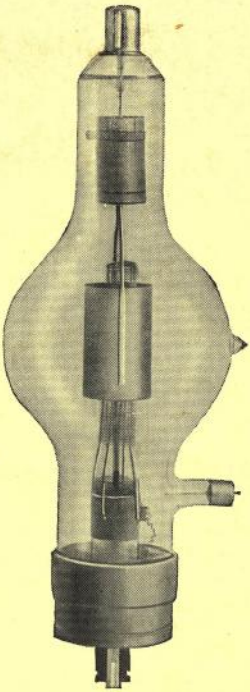
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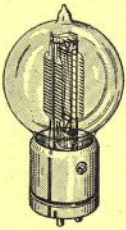
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Electron Tubes
The Heart of the Modern Radio Phone

No. 1—1000-Watt Transmitting Tube.
No. 2—250-Watt Transmitting Tube.
No. 3—50-Watt Transmitting Tube.
Nos. 4 and 7—5-Watt Transmitting Tubes,
(also used as power amplifiers)
No. 5—Detector and Amplifier (storage battery).
No. 6—Detector and Amplifier (dry battery).

Preface

Radio is taking its place in modern life alongside the telephone, the phonograph, and the automobile. Civilization is communication, and radio is the unique supplement of all other means of communication. With its novelty and mystery, radio has an appeal to everyone, but it has also rapidly increasing real utility.

The life of the sailor in mid-ocean depends upon it. It is of routine commercial value to the business man and it is a great force for the education and entertainment of the whole population. One who is new to the subject wants to know what radio really does and can do; what is needed to receive or use radio; and how it works. This handbook aims to give just that information without too much technical explanation. Practical information on the use of receiving apparatus is given in Chapter 2, explanations of how it all works being left to later chapters.

In the apparatus section the reader will find illustrations and detailed description of the various pieces of equipment that enter into a modern radio phone receiving set. An effort has been made to make this section as complete as the limited space assigned it will allow. It will often facilitate understanding of the text matter to turn to this section and see an illustration of the apparatus discussed. The reader is urged to use the apparatus section for this purpose.

Radio is bound to seem mysterious at first. It is invisible; it can not be sensed directly, like sound or light. It does not stay on a track or wire but penetrates everywhere. It is a most willing servant of mankind, carrying all manner of signals, sounds, electric currents, and messages.

The authors and publishers will be glad to hear from holders of the book telling of any errors or of important points not fully covered.

Address all communications to LEFAX, Inc., Sheridan Bldg., 9th and Sansom Sts., Phila., Pa.

Free Service

New developments in radio including new apparatus and hook-ups will be described in *Radiofax*. This publication will be mailed to all holders of the handbook for one year without charge. *Radiofax* pages are the same size as the handbook and thus can be easily transferred.

Fill out and mail the postal card immediately.

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CHAPTER ONE

WHAT RADIO DOES

The word radio comes from "radiate." Radio is an electrical action which is radiated out in all directions through the air. Just as there is one kind of electrical action known as the electric current which goes along wires and turns machinery and lights our homes, so radio is another form of electricity. Instead of going along wires it radiates out in all directions from the place where it is started. Because radio thus produces an electrical effect at a distance without connecting wires, it was formerly called wireless. Radio has possibilities that are not found in the ordinary electric current, just as an automobile is free from some limitations of a trolley car confined to tracks.

Since radio spreads out in all directions from the place where it is started, its effect can be picked up at an unlimited number of places simultaneously. It may thus be spoken of as a highly democratic, even communistic, kind of communication, being available to everyone. It is very similar to sound waves. Sound similarly spreads out in all directions through the air and can be heard by many people simultaneously. Radio is not sound, however, because it is electrical in its nature. Radio is in fact very much like light—except that instead of using our eyes to detect it, we use special receiving instruments. Radio is practically instantaneous. It spreads out with the same speed as light, 186,000 miles per second.

As will be explained in chapter 4, radio consists of electric waves radiated out from a special kind of outfit called a radio transmitting station. It will also be shown how these electric waves are produced by the action of electric current in the transmitting station. As soon as the reader realizes, however vaguely, this fundamental fact that radio consists of electric waves proceeding out from the transmitting station, he is well started on the road toward understanding what radio can and can not do. The form of the waves is determined by the nature and variations of the electric current at the transmitting station. This current can be varied in accordance with the dots and dashes of ordinary telegraphic signalling or can be the kind of current flowing in an ordinary telephone line. Further consideration of how the radio wave

can thus carry any form of signal or even speech or music may very well be deferred until chapter 4.

In the use of the ordinary wire telephone the sound produced at the transmitting end is converted into a varying electric current which flows along the wires, this current being changed back again into sound in the telephone receiver at the other end. Radio telephony is similar except that there are no connecting wires. There must be arrangements at the transmitting end for converting the speech into an electric wave and at the receiving end arrangements for converting the received electric wave into sound. The great difference between the two is that the electric action has been carried by means of electric waves passing through the air instead of by means of electric current passing along a wire. Consequently it is possible to transmit and receive by radio anything that could be transmitted and received by the wire telephone, radio having the great additional feature (advantage in many respects and disadvantage in some) that it can be received by anyone in any direction from the transmitting station. This book will deal primarily with radio telephony, as this is of most interest. There is little difference in the receiving of telephonic or telegraphic signals.

Uses of Radio.—Radio has taken its place as one of the great means of communication comparable with the ordinary telephone and the newspaper. In the communication business proper it is recognized as an additional agency of communication comparable with the wire lines and the cables. It is particularly useful in marine and aerial transportation both in furnishing special aids to navigation and in carrying on of communication, especially distress signals. It is perhaps most similar and supplementary to the newspaper in the work of broadcasting news, entertainment, etc. It is worth while to consider the following list of the principal uses of radio:

1. Broadcasting.
2. Communication with moving ships, aircraft, etc.
3. Transoceanic communication.
4. Communication between two points on land.
5. Non-communication uses.

Radio broadcasting is the most recent but the most important use of radio. It is now possible in most sections of the United States, by means of suitable receiving apparatus which the layman can learn to operate, and which may be easily installed in any private home or office, to pick up valuable and interesting news, information, and music, broadcasted on regular schedules by various radio telephone transmitting stations. By the addition of amplifiers and loud speaking horns, now on the market, the speech or music received may be reproduced as loud as desired,

and thus be made available to large gatherings of people without the necessity of separate head receivers for each listener. The value of the radiophone broadcasting service is rapidly being increased by the construction of additional transmitting stations in various sections not now reached with regularity. The services of existing stations are being extended; many stations are sending out regularly such items as weather forecasts, market prices and data, stock market reports, the latest news, standard time signals, church services, theatrical entertainments, speeches, lectures, and music of all kinds. Broadcasting is discussed in later sections of this chapter.

The use of radio at sea was the first important application of radio and still continues one of its most important services. Besides regular messages between ships and land, reports of ships' positions are made by radio and ships receive from shore stations weather warnings and general and hydrographic news. So important is the use of radio on ships that the use of radio on shipboard is compulsory and no vessel can leave a United States port without a certificate from a U. S. radio inspector that its radio equipment is in working condition. Coast radio transmitting stations are required to cease operating for a period of 2 minutes every 15 minutes, to listen for possible distress signals from ships. This is the reason that broadcasting stations near the seacoast interrupt the broadcasting once every 15 minutes.

The use of radio on commercial aircraft is practically universal. In foggy weather the use of radio on an airplane is as necessary as on a ship at sea. It is now technically possible to connect the ordinary wire telephone lines to the radio apparatus so that conversation can be carried on from the ordinary house telephone with a distant ship or airplane which is equipped with radio apparatus. It is only a question of time till the telephone companies furnish such service regularly.

Radio is an alternative to the submarine cable for transoceanic communication. Commercial radio service across several oceans has been maintained for several years in competition with the cables. It has the great additional advantage that persons on two different continents can speak to one another directly instead of through code telegraphy, an advantage not possible with the cable. Such radio telephony however is not yet a regular service. To cover these great distances very high power radio stations are used. All of the great nations are now extending their high power radio systems, their great usefulness to business being evident. For this kind of service the fact that radio can be picked up in many places in all directions from the transmitting station is a disadvantage and indicates

that for transoceanic communication radio can never entirely replace the cable.

For reasons which will be explained later, radio messages more or less interfere with one another. Consequently it is necessary that communication which can quite readily be carried on by other means than radio should utilize such other means. Radio is, therefore, not used much for communication between two points on land inasmuch as wire telephony or other means of communication could be used. There are, of course, exceptions in the case of deserts, mountain regions, remote forest regions, etc. One kind of communication between two points on land where radio may be suitable is communication with moving trains and other vehicles. This has been done but not actually developed to any considerable extent. It is in fact likely that means will be found to utilize electric currents guided along the rails or nearby wires for railway communication so that radio will not be needed for this purpose. The only extensive use of point-to-point radio communication on land is the radio work of amateurs. In the relaying of messages across the country an extensive communication system has been built up by the United States amateurs.

A large number of uses of radio which are not communication have already been developed. Among these are various aids to navigation. A radio station automatically sending out signals acts as a radio beacon. These signals can be received by ships or aircraft and by means of them the vessel can navigate just as by the aid of beams from a lighthouse. The United States Bureau of Lighthouses is installing a number of such radio beacons. Various radio navigational aids for aviation are being worked out. One that has been developed is the use of radio signals at a landing field to facilitate airplane landing. Another non-communication use of radio is the transmission of time signals giving standard time twice daily in the United States. By means of radio, distant control of any desired machinery or motion is possible. The radio signals can operate a relay which will throw into or out of service any desired machinery. In this way aircraft and ships are started and operated without any persons on board. Methods have been worked out for transmission of photographs, thumbprints, and writing by radio. This is still in the experimental stage, but handwriting has been reproduced across the Atlantic by radio.

Importance of Broadcasting.—It was only when radio began to be used for broadcasting that it attracted the widespread interest of the general public. Broadcasting is transmission to an unlimited number of receiving stations without charge at the receiving end. So long as radio was used with only one particular

receiving station in view to receive the message, its greatest possibilities were untouched. Since it spreads out in all directions and can be received by an unlimited number of persons, it is obviously of most use when the material transmitted is of interest to a large number of people. Weather and other news of interest to ships has been broadcast by radio telegraphy (code) for many years. The year 1921, however, saw the real beginning of broadcast radio service. Government news of market conditions of interest to farmers was transmitted from six Government stations. This information was transmitted in telegraphic code. It was picked up by amateurs and distributed to the newspapers and to farmers in various ways. It was not long until universities, electric manufacturing companies and others secured permission from the Government to broadcast this information by radio telephone. At the same time a number of electric companies, newspapers, etc., began sending out music and lectures by radiotelephone. When people learned that actual words and music could be heard, radio bounded into popularity. Since, moreover, only relatively simple and cheap receiving apparatus was required to hear all of this material, the popular interest in radio grew rapidly. In 1921 also the broadcasting of important financial and political news by radiotelephone was begun in Germany and Holland.

The importance of radio broadcasting as a means of disseminating news, instruction, and entertainment is generally recognized. It is an established and valued supplement to the newspaper, the theater, and the phonograph, and excels each of these in some respects. The proper development of such service has received the attention and guidance of the Government, and all sorts of organizations, newspapers, communication companies, schools, churches, and other Government and commercial concerns have provided radio broadcasting service. It is not possible for all the broadcasting to be done that all interested would desire, because of the interference of one radio transmission with another. This matter is regulated by the U. S. Department of Commerce.

An interesting illustration of the value of broadcast news is the utilization of such service by exploring expeditions. Arctic exploration parties carry radio transmitting and receiving apparatus, and both receive the daily news and entertainment from high power broadcasting stations and send out stories of their adventures.

Broadcasting Wave Lengths.—In the early development of radio broadcasting, all entertainment and general news was transmitted on the "wave

length" of 360 meters, and official Government news on the wave length of 485 meters. This matter of wave length is of the greatest importance. The waves which constitute radio are all in the same air and so are capable of interfering with each other. The thing that saves the situation and makes it possible to use radio at all is that it is possible to "tune" radio receiving apparatus so as to receive waves of a particular wave length (or wave frequency) and not receive those of other wave lengths. "Tuning" will be explained later. Practically its effect is that turning to different points on the dial on the receiving set makes the set pick up waves of different wave lengths.

The general idea of wave length is explained in chapter 4, page 13. It can be readily understood by comparison with sound waves. A sound wave of higher frequency has a shorter wave length than a sound wave of lower frequency. The same thing is true of radio waves. The wave length or frequency is determined by what takes place in the transmitting antenna. Any particular transmitting antenna sends out a radio wave of some particular wave length or frequency just as a piano string when sounded sends out a sound wave of some particular wave length or frequency. The wave length is the distance from one wave crest (or maximum) to the next. Radio wave lengths are anywhere from 100 to 25,000 meters. The meter is about 39⅜ inches, and is the unit of length used all over the world except in the United States and the British Empire. Wave length has nothing directly to do with the distance to which a radio wave spreads out. Similarly, a sound wave or a water wave may have a wave length of one foot but such a wave could travel a distance of very many feet.

All of the more popular broadcasting being done on the same length (360 meters), it was impossible to avoid some interference. The loudness of the received signals decreases with distance from the broadcasting station, so it is possible for that reason to hear a nearby station without being disturbed by a remote station. When the broadcasting stations were near together, however, it was necessary for them to broadcast at different times of day. When this was not done, it was still sometimes possible to "tune in" the station desired and "tune out" one not desired because the wave lengths were usually not adjusted accurately and one might be a little greater than 360 meters and one a little less.

The interference became so troublesome that it was necessary to make arrangements whereby broadcasting stations could have different wave lengths. Radio is regulated, and wave lengths are assigned, by the U. S. Department of Commerce. The Department called a conference in March, 1923, to draw up a plan which would give more wave lengths for broad-

casting and still leave enough for the various other uses of radio, such as ship and aircraft communication. This conference divided broadcasting stations into the following classes:

Class A stations—that is, stations equipped to use power not exceeding 500 watts. In this class the radio inspectors, in co-operation with the station owners, assign distinctive wave lengths to each station so far as is possible in the area from 222 to 300 meters.

Class B stations—that is, stations equipped to use from 500 to 1000 watts. These stations are licensed on special wave lengths from 300 to 345 and from 375 to 545 meters. There are forty distinct wave lengths available in this range, and each is assigned to a certain locality, there being no duplications except for a few cases of use of the same wave by two localities, one on the Atlantic and the other on the Pacific Coast. Where more than one Class B stations operate in the same locality, they must operate on the same wave length and avoid interference by operating at different hours.

Class C stations—comprising all stations originally licensed for 360 meters. In this class no new licenses will be issued for stations on 360 meters. Stations which do not wish to move under the general plan may remain at 360 meters, but they will necessarily be subject to some interference at best.

Broadcasting Development Class—To encourage scientific development of broadcasting and the apparatus used for this purpose, licenses of this class will be issued to owners of stations having transmitting and receiving equipment of their own design and manufacture. Such stations are to be used for the development and improvement of broadcasting and to have adequate laboratory and manufacturing facilities and personnel, with sufficient skill, training and experience to insure progress in development work and the best obtainable quality of broadcasting.

The recommendations of the conference were placed in effect on May 15, 1923, in the case of class B stations. The changes in other stations followed shortly thereafter. The complete schedule of wave lengths for all classes of radio communication is given below.

One of the best provisions of the new arrangement is that by which the higher power broadcasting stations are assigned individual waves in the range from 300 to 545 meters (1000 to 550 kilocycles). Only one broadcasting station on each of the wave frequencies within this range is in operation at any given time (except for some duplication of waves on the Atlantic and Pacific coasts which is being tentatively allowed by the Dept. of Commerce). That is, waves approximately forty in number are ten kilocycles apart. This means that a

person having a receiving set so good that he can receive from all parts of the country is not in danger of hearing a beat note from two stations on nearly the same wave frequency, nor will two stations be heard working on the same wave frequency. This has resulted in the development of extraordinarily perfect broadcasting service and has greatly stimulated the development of high quality receiving apparatus.

The conference recommended that wave frequency expressed in kilocycles be used primarily, wave length in meters being given in parenthesis when desired. We urge our readers to familiarize themselves with and think in terms of kilocycles as soon as possible, inasmuch as waves are now assigned in even values in kilocycles, the wave length in meters being calculated therefrom. It is expected that the use of the term "wave length" in radio will gradually disappear.

Wave Length Regulation.—Not only in broadcasting but in all uses of radio, the whole success of the communication depends on proper use of the wave lengths. Certain specific wave lengths are assigned for certain purposes by international and national laws, and technical requirements determine the use of some others. The longer waves are more suitable for longer distances, because short waves are very much more absorbed or impeded by the surface of the earth over which they travel. Thus wave lengths from 8,000 to 24,000 meters are used in transoceanic communication. Very short waves carry specially well at night. Amateurs (who work mostly at night) use wave lengths less than 200 meters. The various other uses of radio are on wave lengths intermediate between these extremes.

Every transmitting station in operation makes it more difficult for receiving stations to hear other transmitting stations without interference. Therefore, no business which can be transacted by using other methods of communication should be conducted by radio. The number of wave lengths available for the use of radio stations is limited and in densely populated regions and in all important seaports the problem of radio interference is an extremely serious one.

Time Signals by Radio.—The system of transmission of time signals is as follows: Beginning 5 minutes before the hour on which the time signals close, the transmission of a series of dots is commenced. One dot is sent at the beginning of each second of time; the 29th second of each minute is omitted, and the last five seconds of each minute are omitted for the purpose of enabling the one who counts the signals to make preliminary observations before the closing signal. At the close of the final minute, the last 10 seconds are omitted. Then at the exact hour a long dash is transmitted, whose beginning marks the hour.

WAVE FREQUENCY ALLOCATIONS

Wave Frequency, Kilocycles, per Second	Wave Length, Meters	Class of Service
Above 2300	Below 130	Reserved. (See Note 1.)
2300	130	Government, CW, exclusive.
2300	130	Reserved. (See Note 1.)
2100	143	
2100	143	Government, CW, exclusive.
2100	143	Reserved. (See Note 1.)
2000	150	
2000	150	Amateur, CW, ICW, Phone, exclusive.
1700	176	
1700	176	Amateur, CW, ICW, Phone, Spk, exclusive.
1500	200	
1500	200	Special amateur, and technical and training schools, CW, exclusive.
1350	222	
1350	222	Aircraft, CW, ICW, Phone, non-exclusive.
1300	231	
1350	222	**Class A broadcasting, Phone, non-exclusive.**
1000	300	
1000	300	Marine, CW, ICW, Spk, non-exclusive. (Note 2.)
1000	300	
870	345	**Class B broadcasting, Phone, exclusive.**
835	360	**Class C broadcasting, Phone, exclusive.**
800	375	
667	450	**Class B broadcasting, Phone, exclusive.**
667	450	Marine, CW, ICW, Spk, exclusive. (See Note 3.)
667	450	
550	545	**Class B broadcasting, Phone, exclusive.**
550	545	
500	600	Marine and aircraft, CW, ICW, Spk, exclusive.
500	600	Marine and aircraft, CW, ICW, excl. (Note 2.)
500	600	
445	674	Marine and aircraft, CW, ICW, Spk, exclusive.
445	674	Government, CW, non-exclusive.
445	674	
375	800	Marine and aircraft, CW, ICW, Spk, exclusive.
375	800	Radio compass, CW, ICW, Spk, exclusive.
375	800	
315	952	Marine, Phone, exclusive.
315	952	Government, CW, ICW, Spk, exclusive.
315	952	Reserved.
300	1000	
300	1000	Radio beacons, CW, ICW, Spk, exclusive.
300	1000	Reserved.
285	1053	
285	1053	Marine, Phone, exclusive.
275	1091	
275	1091	Government, CW, ICW, non-exclusive.
275	1091	Marine, Phone, exclusive.
250	1200	
250	1200	Government, CW, ICW, non-exclusive.
250	1200	Marine, Phone, exclusive.
235	1277	
235	1277	University, college, and experimental, CW, ICW, exclusive.
230	1304	
230	1304	Government, CW, ICW, Spk, exclusive.
190	1579	
190	1579	Marine and point-to-point, non-government, CW, ICW, Spk, exclusive.
120	2500	
120	2500	Government, CW, ICW, Spk, exclusive.
95	3158	

Note 1.—Available for special licensing by the Department of Commerce.

Note 2.—The 1000 and 500 kc/s (300 and 600 meter) waves are for calling and distress purposes, with a minimum of traffic.

Note 3.—Mobile service on the 667 kc/s (450 meter) wave is to be stopped between 7 and 11 p. m. local standard time, and to be transferred in so far and as soon as practicable, to wave frequencies below 500 kc/s (above 600 meters).

Factors Affecting Range of Receiving Sets.—The distance over which radio can be picked up varies with time of year, day and night, and other factors. It is sometimes possible to hear a station 1000 miles away at night while 200 miles would be the greatest distance covered in the day. An explanation of this, and of the fluctuations of signals that sometimes occur at night and other variations, has been published by the authors in "Radio Signal Fading Phenomena," in the Journal of the Washington Academy of Sciences, 11, p. 245, 1921. On account of disturbances of the electrical condition of the atmosphere, during midsummer, radio reception during daylight hours may be occasionally interrupted. At times, during the summer months, the strays may completely drown out the radio signals picked up by the receiving set. The idea that the addition of sensitive amplifiers to the receiving set will relieve the situation is erroneous. The amplifier amplifies the strays along with the incoming signal, so the amplified signal is often less intelligible than the signal received on a simple detector.

During severe electrical storms sometimes it is not only impossible to receive any messages, but it may be unwise, especially if the storm is accompanied by lightning discharges. At such times the antenna should be grounded to protect the apparatus and no attempt made to receive radio messages. Occasionally the transmitting range of a station will be limited in a certain direction owing to an intercepting dust storm. These atmospheric disturbances which give trouble in the use of receiving sets are discussed further, near the end of Chapter 2.

Present Status of Radio.—Radio is rapidly developing and popular appreciation of it is accelerating its expansion to fill the unique field of usefulness to which it is adapted. A word is desirable as to its shortcomings, so loudly are its advantages heralded. While the spreading out in all directions is an advantage for broadcasting and some other uses, it is a disadvantage in other ways. Radio lacks the secrecy or individual character of communication by wire, and cannot take its place. There is no calling up in radio with a call bell, as in wire telephony. That is a possibility, but it has not been developed; one way of doing it now is to use a powerful amplifier and loud-speaking telephone receiver.

CHAPTER TWO

HOW TO RECEIVE RADIO

As explained in chapters 1 and 4, radio may be either telephony or telegraphy, that is, one may hear the actual voice of the person who is speaking into a radio telephone transmitting set, or one may hear the long and short buzzing sound constituting the dots and dashes of the telegraph code. Fortunately the same receiving apparatus may be used to receive either telephony or telegraphy, except for the special kind of radio telegraph signals which are called continuous wave signals and usually spoken of as "C W" Special equipment described in Chap. 5 is required for this purpose.

While the law requires that one must have a license from the United States Department of Commerce in order to operate a radio telegraph or radio telephone transmitting station*, there is no requirement whatever regarding the operation of a radio receiving station. It would obviously be impossible to determine where all the receiving stations are located, now that antennas can be installed indoors, or to enforce any law requiring that they be licensed unless the receiving stations also did some transmitting. It happens that certain kinds of receiving apparatus, which will be described later, do behave as very weak radio transmitting sets and so may be heard by any other nearby receiving station. It is likely that fewer of the receiving sets, which can also act as feeble transmitting sets, will be sold in the future, but often those which are now in use can be so adjusted in their operation as to avoid their doing any transmitting. This is desirable in order that they may cause no trouble to other persons who are trying to receive radio from a distance.

Essential Parts of a Receiving Station.—The connections between the essential parts of the simplest type of receiving station are shown in Fig. 1. The principal apparatus is the "receiving set." Its main connections are to the "antenna" and to the "ground." The received signals come into the receiving set through these connections. In the receiving set they are converted into an electric current which produces the

*Information regarding licenses for radio transmitting stations and operators may be obtained from a pamphlet, "Radio Communication Laws of the United States," which may be purchased for 15 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

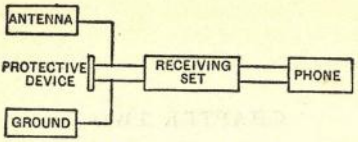


Fig. 1—Essential Connections of a Receiving Station.

sound in the "phone." The phone is either a pair of telephone receivers worn on the head of the listener or else a loud-speaking telephone receiver which can be heard all over the room. The received signals will not be powerful enough to operate a loud-speaking telephone receiver with the simpler types of sets unless the signals come from a powerful transmitting station not more than a few miles away.

The "receiving set" is subdivided into "tuner" and "detector," as shown in Fig. 2.

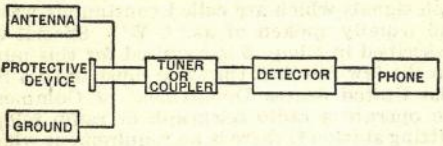


Fig. 2—More Detailed Connections of a Simple Type of Receiving Station.

Selection of Receiving Set for a Given Purpose.—The selection of a radio receiving set depends on a number of factors which should be pretty well in the mind of the user before he purchases or constructs his station. First among these are the wave length and the distance to the radio transmitting station or stations which he desires to hear. If only the reception of the short-wave broadcasting stations is desired there is no need of securing a set which will receive both short and long waves. In addition the user must decide whether he will be content to receive signals which are just audible when the telephone receivers are held tightly against his ears or whether he desires to have signals so loud as to be heard through an entire room. He must also decide whether he is willing to pay for a receiving set which is nicely finished in appearance, or whether he is content to have a more ordinary looking set. Obviously the more he demands from his receiving set the more he will have to pay for it. An additional feature which it is desirable for the listener to know is the power of the transmitting station which it is desired to hear. This can be determined by reference to the map in the appendix.

One must not be misled into thinking that very simple apparatus can accomplish great results just because of reports of very long distances over which radio has been received on some occasions. These

extraordinarily long distances are usually obtained at night and are very irregular. If one expects to make the fullest use of his radio station he must plan to put in a station which will be sure to receive regularly the service which he desires. He will then receive as extra service the more distant stations which may be heard when transmission conditions are favorable. It must

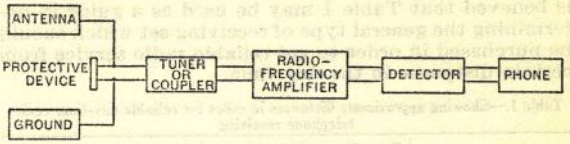


Fig. 3—Essential Connections of Receiving Station with Radio-Frequency Amplifier.

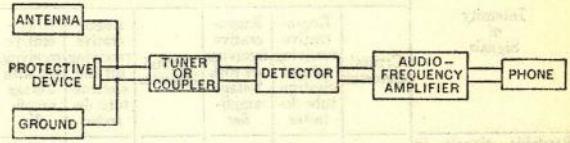


Fig. 4—Essential Connections of Receiving Station with Audio-Frequency Amplifier.

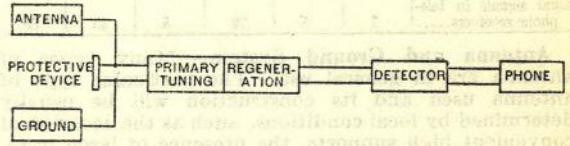


Fig. 5—Essential Connections and Controls of Receiving Station with Single-Circuit Regenerative Receiving Set.

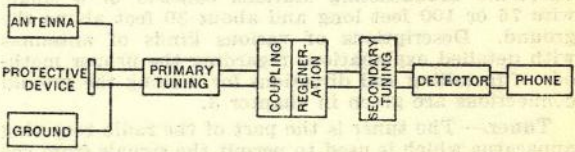


Fig. 6—Essential Connections and Controls of Receiving Station with Two-Circuit Regenerative Receiving Set.

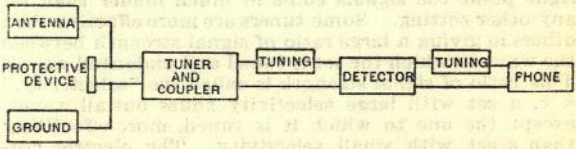


Fig. 7—Essential Connections and Controls of Receiving Station with Three-Circuit Regenerative Receiving Set.

also be emphasized that radio carries much farther at night than in the day time. This is especially noticeable at a distance of fifty miles or more from the transmitting station. For reliable radio service in the day time one must, therefore, have much better radio receiving apparatus than is necessary for reliable service at night. While very much depends upon the design of the particular type of receiving set which is used, it is believed that Table 1 may be used as a guide in determining the general type of receiving set which should be purchased in order to get reliable radio service from certain distances in the day time.

Table 1.—Showing approximate distances in miles for reliable day-time radio telephone receiving

Intensity of Signals	From Transmitting Station having 50 watts in antenna			From transmitting station having 500 watts in antenna		
	Crystal Detector	Regenerative receiving set and electron tube detector	Regenerative receiving set with 2-stage amplifier	Crystal Detector	Regenerative receiving set and electron tube detector	Regenerative receiving set with 2-stage amplifier
Readable signals in telephone receivers..	8	20	40	35	65	100
Loud signals in telephone receivers.....	1	8	20	5	35	65

Antenna and Ground System.—Many types of antenna are in general use. The particular type of antenna used and its construction will be usually determined by local conditions, such as the location of convenient high supports, the presence of large trees, and third the dimensions of the property. A good form of antenna for receiving from most of the radio telephone broadcasting stations consists of a single wire 75 or 100 feet long and about 30 feet above the ground. Descriptions of various kinds of antennas with detailed explanations regarding the proper methods of installing and directions for making the ground connections are given in chapter 3.

Tuner.—The tuner is the part of the radio receiving apparatus which is used to permit the signals from the desired station to be received while all other signals are kept out so far as possible. When it is set at the right point the signals come in much louder than for any other setting. Some tuners are more effective than others in giving a large ratio of signal strength between the wave to which the set is tuned and undesired waves. This ratio of signal strength is called the "selectivity," *i. e.* a set with large selectivity shuts out all waves, except the one to which it is tuned, more effectively than a set with small selectivity. The electric currents produced in the tuner are converted by the detect-

or into a form suitable for actuating the diaphragms of the telephone receivers. The knobs and handles which are located on the front of these tuners are for the purpose of changing the wave to which the apparatus is tuned, that is, the turning of these knobs results in tuning out a station which uses one wave and tuning in a station which uses another wave. In some of the types of tuners there is employed a special circuit for increasing the loudness of the signals even before they reach the detector. Such a circuit is called a regenerative circuit and for its adjustment one and sometimes two knobs are required.

Detector.—The detector used with a present day receiving set is ordinarily either a crystal detector or an electron tube detector. Either type of detector may be built into the same panel or box as the tuner. In some cases the detector is mounted on a separate stand or panel.

In the simplest sets the tuner is a single coil of wire with an arrangement for putting different amounts of wire in circuit. In more complicated sets the tuner includes a "coupler" and other parts. For further information on couplers see page 16 of this chapter.

The crystal detector usually consists of a fine wire or other metal point (sometimes called a cat whisker), resting lightly upon a small piece of galena (lead ore). All galena is not equally sensitive nor are all spots on a given crystal sensitive. When a crystal detector is used it is very desirable to employ a test buzzer with a dry battery to determine when the detector is adjusted to a sensitive condition. The use of the test buzzer is described under Preliminary Adjustments, page 9, chap. 2.

In adjusting a crystal detector the end of the fine wire is touched lightly to one spot of the crystal after another until the sound of the test buzzer or of the desired signals, or of atmospheric disturbances, is heard in the phone. The adjustment is difficult to maintain permanently and it is necessary to make sure each time the set is used that the wire is touching a sensitive spot on the crystal.

The electron tube detector has the advantage that it does not require special adjustment of a delicate contact to make it sensitive. Its sensitivity can be kept invariable and, it may also be much more sensitive than the ordinary crystal detector. The electron tube detector is sometimes called a vacuum tube, audion, or triode. This type of detector consists of an incandescent electric bulb very similar to an ordinary electric light bulb except that there are other parts sealed into it in addition to the heated filament. The filament is lighted by a battery called the "A" battery, usually a storage battery of about 6 volts though this depends upon the type of electron tube used. Another battery

is employed in connection with the electron tube. This is called the "B" battery and usually consists of a number of small dry cells sealed in a block as a unit.

The frontispiece shows a number of electron tubes of various types designed for use as detectors, amplifiers and transmitters. The more recently developed tubes which operate on dry batteries are smaller than the others and are convenient for use in small portable receiving sets. In Fig. 8 there can be seen the several

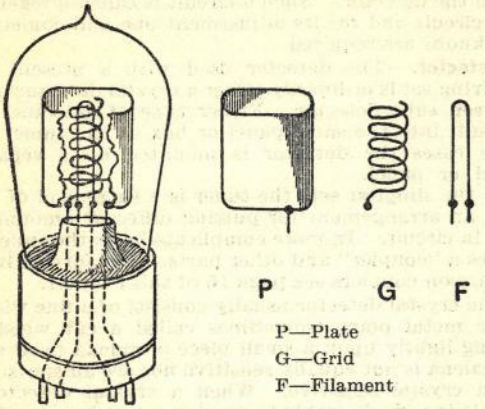


Fig. 8—Electron Tube

parts or elements of an electron tube. These are the filament, grid, and plate which are mounted inside of the glass tube from which the air has been pumped out. Each of these elements is separated from the other by a small space. There are two connections made to the filament, one at each of its ends. There is only one connection made to the grid and one connection to the plate. These four connections come to the four prongs on the base of the tube. The filament is surrounded by the grid, which is usually a spiral coil or lattice work. The plate is located outside of the grid and is usually cylindrical but sometimes flat.

The construction features of tubes used as amplifiers are identical to those of the detector tubes. They differ in the degree of vacuum produced within the bulb. The amplifiers have less air remaining in them.

Telephone Receivers.—The head sets or telephone receivers used for receiving radio are nearly the same as the standard telephone receiver which is very familiar. The principal difference is the form of construction. On account of the long periods of time for which radio head sets are often worn by an operator, these are made as light and as compact as possible and are therefore sometimes called watch case receivers. They

are mounted either singly or in pairs and are usually provided with a head band to hold them in place against the operator's ears. Telephone receivers designed for use with radio receiving sets usually have much more wire wound upon the magnets in order that a small current through the receiver may produce a louder sound from the diaphragm. As an indication of the amount of wire used in winding the telephone receiver magnets the receivers are ordinarily rated by the resistance of this winding. Thus some receivers are 1000 ohms and others 2000 or 3000 ohms. It is impossible, however, to judge the performance of a telephone receiver by resistance alone, since many other factors enter into the determination of its efficiency. The two receivers of the head set are usually connected in series.

Amplifiers.—The amplifier is a device employing one or more electron tubes in order to make the received radio signals louder than they would be without it. Many amplifiers have two or three electron tubes and are called "audio-frequency" amplifiers. The "audio-frequency" currents which are thus amplified are those which pulsate at a frequency which can be heard by the human ear, *i. e.*, ordinarily between 16 and 10,000 cycles per second. They correspond to the frequencies of sound waves produced by the voice and by musical instruments. They are connected between the detector and telephone receivers. There are also being manufactured amplifiers called "radio-frequency" amplifiers which are connected between the tuner and the detector. Radio-frequency amplifiers serve to amplify the currents of the tuner before they are connected to the detector. These two types of amplifiers are very similar in outward appearance. Since the amplifiers employ electron tubes, it is necessary to use batteries to light the filaments of these tubes as in the case of the detector tube referred to above. It is also necessary to use the small blocks of dry batteries in the plate circuits of these tubes, The connections of the amplifier and detector are ordinarily arranged to make possible the use of a single storage battery for lighting the filaments of all of the tubes and a single "B" battery for connection to the plate circuits of all of the tubes of a single receiving set. The voltage of the "B" battery may be anything between 40 and 100 volts. Somewhat louder signals are secured by using the higher voltages suggested. The detector tube, however, rarely requires a voltage over 22½.

Receiving sets are now on the market which utilize specially designed electron tubes requiring a comparatively small current to light the filaments. These tubes can be operated from dry batteries, unless there are several tubes in the same receiving set. In the latter case the total current required is great enough to make storage batteries more economical. Receiving

sets have been developed in which the filaments of the tubes are lighted from the commercial lighting circuit, but no one should attempt to improvise such a connection without expert advice. Until further improvements are effected, the storage battery will remain the most satisfactory means of operating the vacuum tubes.

Storage Battery.—A storage battery can be used with a radio receiving set for only a limited time without recharging. In order to recharge the battery and put it in condition to supply further current to the receiving apparatus, it is necessary to connect it through special apparatus with the power or lighting circuit or send it to an electrical shop to be charged. A number of devices are made for use in charging a small storage battery from the house lighting circuit. Some of these can be connected to an ordinary electric light socket and require very little attention. One must be sure to know by inquiring of his electric light company whether his lighting power is alternating or direct current. This makes an important difference in the type of battery charger which is suitable. When the battery is connected to the electric light circuit through the charger and the necessary initial adjustment of the charging current is made, it can ordinarily be left in this condition, that is, "on charge" for a number of hours without attention. The time of charge depends upon the capacity of the battery and the amount which it has been used since it was last charged. It is advisable to use a hydrometer as a tester in order to determine whether the battery needs recharging. It is not desirable to permit the battery to become so greatly discharged as to fail to light the filaments of the electron tubes to their normal brilliancy. Storage batteries need to have distilled water added to them at intervals. This can be secured at any automobile or battery service station. Detailed instructions for care and operation are furnished with each battery by the manufacturer.

Loud Speakers.—Loud speaking reproducers are on the market which can be substituted for the telephone receivers in any receiving set which employs an amplifier. The use of this loud speaker makes it possible to hear the radio signals throughout an ordinary room though the volume of this sound varies with different types of reproducers. Where exceptionally great volume of sound is required it is necessary to employ additional amplifiers in order to take the fullest advantage of the loud speaking equipment. There is the disadvantage, however, that when great amplification is used, especially with improperly designed equipment, there is a considerable amount of distortion and thus the quality of the speech is impaired. The clearness and distinctness of the signals will therefore in general

be best when received with head telephone receivers. However, a number of very satisfactory loud speakers are now on the market which, if not forced unreasonably, will give excellent results.

Manipulation of Receiving Sets.—In view of the differences of manipulation of the various types and makes of radio receiving sets, it is impossible to give a single general outline of procedure which can be followed with all sets, but a few general suggestions will be given for the handling of three specific types: (1) the single circuit; (2) the coupled circuit; (3) the three-circuit receiving set. This classification is based on the number of control handles which must be turned in tuning the receiving set to the wave length or frequency of the station which it is desired to hear. Complete operating instructions are furnished by the manufacturer with each set.

The parts of a single circuit receiving set are shown diagrammatically in Fig. 5. It may be seen here that there is but a single tuning element, though adjustments of other parts of the set must be made.

The coupled circuit receiving set is shown in Fig. 6 and the three-circuit receiving set in Fig. 7. The diagrams show how the several tuning elements are associated with the other parts of the set.

Preliminary Adjustments.—It is first necessary to make sure that the antenna is properly connected to the receiving set and that the ground connection is thoroughly made. In case an antenna switch is used, this should be thrown to the receiving position. Next the detector must be adjusted to a sensitive condition. In the case of a crystal detector this involves adjusting the contact of the fine wire or "cat whisker" until it touches a sensitive spot on the surface of the crystal. This can be determined by noting when the loudest sound is heard in the telephone receivers when the test buzzer is operated. If such a test buzzer is not included in the receiving set, a simple one can be connected as shown in Fig. 11. In case the detector is an electron tube it is necessary to light the filament by closing the filament switch. In some receiving sets this is done by the mere insertion of the telephone plug. The filament rheostat knob is then turned in the direction which increases the brilliancy of the filament until a slight hissing sound is heard in the telephone receivers. Then the rheostat handle is turned back very slightly to the point where this hissing is no longer heard. In case an electron tube amplifier is used, a slight adjustment of the current through the filaments of the amplifier tubes is also necessary.

Tuning to Broadcasting Stations.—The radio telephone broadcasting at the present time is on certain few wave lengths. Some of the transmitting stations are not tuned exactly to their nominal wave lengths but

deviate from them by about 5 or 10 meters. This means that when the receiving set has once been tuned to a given broadcasting station, only a slight readjustment of the tuning controls enables one to tune in any other broadcasting stations which are using wave lengths only slightly different from this but which are not too distant to be heard. If this fact is kept in mind the manipulation of the set is greatly simplified.

Tuning of Single-Circuit Receiving Set.—Some single circuit receiving sets have but a single tuning control in the form of a knob which is marked with a scale for reading its position. Other types of single circuit tuners have in addition a switch which can be turned to any one of several contact points. In either case the usual procedure is to carefully turn one or both knobs until a position is found where the desired signals are heard. On account of the sharp tuning of the radio telephone signals from distant stations it usually requires much more careful adjustment of the receiving circuits to receive speech or music than is required to receive signals from radio telegraph stations using spark transmitting sets. It is therefore desirable to move the continuously variable control knob rather slowly and listen carefully for a desired radio telephone station. In some receiving sets there is provided a small condenser called a "vernier" condenser which is used for the clearest final adjustment of the tuner. The position of the vernier condenser in a receiving set is given in the section on "Circuit Diagrams" below.

A "tickler" or "regenerative" control, if present, is operated as described on page 12 under "Adjustment of Regeneration."

Tuning of Two-Circuit Receiving Set.—The ordinary "coupled-circuit" or "two-circuit" tuner has three knobs or control handles. These are the primary-circuit tuning control, the secondary-circuit tuning control, and the coupling control. In the first tuning of a receiving station it is advisable to turn the coupling control knob to a point near the position marked "maximum." Then an approximate adjustment may be made of the primary circuit, after which the secondary-control is moved gradually over its entire range. If no signal is heard at any point, the primary control is moved slightly and the secondary control is again turned over its range. By repeating this process a point on both primary and secondary controls will be found where the desired signal is heard most clearly. Then the coupling knob is turned slightly in the direction toward "minimum" and the primary and secondary controls readjusted slightly in order to secure a louder signal. It will be found that the farther the coupling knob can be turned in the minimum direction the less will undesired stations be heard. It will also be found

possible to hear radio telephone signals with a much smaller or looser coupling than spark signals from stations of equal power. It will make the tuning of a coupled-circuit receiving set much easier if one has a chart or table giving the wave frequency or wave length to which the secondary circuit is tuned at each position of the secondary control knob. It will then be possible to set this knob at the position corresponding to the wave length of the desired station, and further adjustment of the primary circuit to this same wave length can be made much more quickly. A chart giving this wave length calibration of the secondary circuit can be made when the receiving set is manufactured. A similar chart can not be made for the primary circuit until after the receiving set is installed and connected to the antenna with which it is to be used, since the wave lengths corresponding to the various positions of the primary control knob depend to a great extent upon the size of the antenna employed.

If there is an additional control knob marked "tickler" or "regeneration" it should be kept in the minimum position until the tuning just described has been accomplished. It can then be adjusted as explained in the section on "Adjustment of Regeneration" on page 12.

Tuning of Three-Circuit Receiving Set.—The tuning of three-circuit receiving set is somewhat more complicated than that outlined above for single circuit and two-circuit receiving sets. In all there are five separate adjustments to be made. Adjustments of these must be changed in turn until the desired signals are received with the greatest intensity. These controls are as follows:

1. Primary circuit (marked on some sets "antenna inductance" or "antenna condenser").
2. Secondary circuit (sometimes marked "grid variometer").
3. Coupling.
4. Plate circuit (sometimes marked "plate variometer").
5. Detector (this is the same adjustment as the filament of the detector tube described under "Preliminary Adjustments.")

In tuning this receiving set the coupling control should be turned to approximately the middle point. A first approximate adjustment should then be made of the antenna inductance or antenna condenser control, setting them somewhat above the middle of the scale if the recommended antenna length of 75 to 100 feet is used. Using both hands rotate the grid variometer and plate variometer dials over their entire scales. These controls should be turned, one following the other, in such a way as to just keep the set from causing a slight hissing

sound in the telephone receivers. When, by successive adjustments of the primary control, the desired signal has been located at a given position of the grid variometer and plate variometer controls, the coupling knob should be turned toward the minimum position until the signal is just barely audible. The primary antenna inductance or antenna condenser control should then be turned to a point which just causes the cessation of the hissing sound in the telephone receivers. The final adjustment to give the loudest signals should be made on the coupling knob.

Adjustment of Regeneration.—In some receiving sets there is provided a control handle which is marked "regeneration" or "tickler." After the receiving set has been tuned to the desired signal the sound can usually be increased by turning the tickler knob from its minimum position until the speech or music begins to be distorted or until a whistling or sizzling sound is heard. The tickler control should then be turned back just below this critical point. In order to economize in the use of the storage battery for lighting the filaments of the detector and amplifier tubes, the filament brilliancy may then be slightly reduced while the tickler or regeneration control is gradually turned toward the maximum position. Since the loudness of the received signals increases greatly as the tickler or grid and plate variometer controls are brought close to the position which gives the hissing sound, it is desirable that these adjustments be made very accurately in order that the loudest sound possible may be obtained without the undesirable noise. It should also be remembered that when the tickler adjustment is turned beyond the hissing or whistling point, the receiving set is usually acting as a weak transmitting set and will cause interference for other receiving sets nearby. This condition should therefore be avoided.

Time spent in indiscriminate tuning and manipulation of the various controls will not produce nearly as satisfactory results as equal time spent in systematically making the tuning, coupling, and regenerative adjustments outlined above. The controls described are the principal ones, though some additional controls, such as vernier condenser, are provided on certain receiving sets for use in obtaining closer tuning adjustment. Such additional adjustments need not be made until the signals from the station desired have first been tuned in.

Detector and Amplifier Units.—Some manufacturers sell detector control panels or units mounted separately from the receiving set or tuner. Most amplifier units are also mounted on separate panels. The terminals of the detector or amplifier panels to which outside connections are to be made are usually clearly marked with the voltage of the battery which is to be

used and with the other necessary instructions. The terminals which are marked grid, filament, etc., and which are usually located at the left hand side of the detector panel should be connected to the corresponding terminals of the receiving set. In connecting the tuner, detector, and amplifier together, the wires used should be insulated, except of course at the ends, and should be as short as possible. In connecting the "A" and "B" batteries to the control panels, care should be taken to connect the positive terminals to the binding posts marked "positive" or "plus" and the negative terminals to the binding posts marked "negative" or "minus." The positive battery terminals are often colored red.

Loud-Speaking Reproducer.—If it is desired to use a loud speaking reproducer, or horn, this should be connected to the amplifier at the telephone terminals or through the plug which is ordinarily used for the telephone receivers. To secure exceedingly loud sounds a power amplifier using the larger types of tubes ordinarily employed in transmitting sets, should be used. Some types of loud speakers require the connection of a storage battery to a pair of additional binding posts located on the base of the loud speaker. It should be remembered that if additional amplifier tubes and loud speaking horns are to be connected to a common storage battery more frequent charging of the battery is necessary. The attachment of a horn to the telephone receivers regularly used with the receiving set is a help in throwing the sound out into the room. Attachments are on sale for clamping a telephone receiver to the horn of a phonograph in place of the reproducer.

Putting Receiving Sets Together.*—In case a person desires to construct his own radio receiving set he can purchase the parts and connect them together to form a set which may be as simple or as complicated as he desires. The accompanying circuit diagrams show

*It is assumed that the reader of this book does not wish to do more than to purchase the separate parts of a receiving set and put them together. The person who wishes to go still farther back and actually construct the parts of simple receiving sets is referred to an authoritative series of brief pamphlets now being put out by the U. S. Bu. of Standards. The first of these is Circular No. 120, "Construction and Operation of a Simple Homemade Radio Receiving Outfit," the second is Circular No. 121, "Construction and Operation of a Two-Circuit Radio Receiving Set." These are obtainable by mailing 5 cents for each to the Supt. of Documents, Govt. Printing Office, Washington, D. C. Later circulars in the series will describe auxiliary condensers, a loading coil to extend range to 3000 meters, an electron tube detector unit, and an electron tube amplifier unit. The issuance of these later circulars will be announced in the Radio Service Bulletin, a monthly publication of the Dept. of Commerce, a year's subscription to which may be obtained by sending 25 cents to the Supt. of Documents at above address. This bulletin contains each month all Government radio news.

the connections which should be made in order to assemble several typical receiving sets. The actual value of many of the coils or condensers required in the various circuits depends upon the wave length of the stations which it is desired to hear. The values given on the diagrams are correct for wave lengths of about 200 to 600 meters.

Inductance Coils.—The various circuit diagrams given in this chapter show inductance coils either as single coils, couplers, or "variometers." The following table is given as a guide in the selection of coils for use in the several circuits. It is not necessary to conform to the exact sizes stated, some variations of tuning being made possible by means of the variometers or variable condensers as well as by the taps provided on the coils. These sizes will be found suitable for tuning to 360 meter, 400, and 485 meter radio telephone stations which broadcast concerts, talks and market reports.

Table 2—Sizes of Inductance Coils for Tuning to Wave Lengths from 200 to 600 Meters.

Coil for single circuit tuner:

Diameter of tube.....4 inches
Length of tube.....5½ inches
Turns of wire.....85, tapped at 25 turns and every 20 turns thereafter.
Size of wire.....No. 18 to 24 B. & S. gauge.
(If for non-regenerative circuit use no smaller than No. 20 wire.)

Coupler:—Dimensions given apply to "loose-couplers." (For variocoupler see 3rd table on page 15.)

Primary Tuning Coil
Diameter of tube.....4 inches
Length of tube.....5½ inches
Turns of wire.....85, tapped at 12 turns and every 6 turns thereafter.
Size of wire.....No. 18 to 24 B. & S. gauge.

Secondary Tuning Coil
Diameter of tube.....3½ inches
Length of tube.....6 inches
Turns of wire.....80, tapped at 20 turns and every 10 turns thereafter.
Size of wire.....No. 18 to 24 B. & S. gauge.
(If for non-regenerative circuit use no smaller than No 20 wire.)
The secondary coupling coil for a "3-circuit" receiving set should have about 30 turns of wire.

Variometer for antenna circuit of single-circuit receiving set:—

Fixed Coil or "Stator."

Diameter of coil.....4 inches
Turns of wire.....35
Size of wire.....No. 20 to 24 B. & S. gauge.

Moving Coil or "Rotor"

Diameter of coil.....3½ inches
Turns of wire.....30
Size of wire.....No. 20 to 24 B. & S. gauge.

Tickler coil:—

Diameter of tube.....3 inches
Lenght of tube.....2 inches
Turns of wire.....30
Size of wire.....No. 24 to 30 B. & S. gauge.

Variometer for grid and plate circuits of 3-circuit receiving set or Variocoupler for 2-circuit receiving set:—

Fixed Coil or "Stator."

Diameter of coil.....4½ inches
Turns of wire.....65
Size of wire.....No. 20 to 24 B. & S. gauge.

Moving Coil or "Rotor."

Diameter of coil.....3½ inches
Turns of wire.....70
Size of wire.....No. 20 to 24 B. & S. gauge.

There are a number of types of inductance coils sold for use in building up receiving sets. These differ chiefly in the details of construction or winding and are variously called "single-layer," "bank wound," "honey comb," "spider web," "duolateral," etc., and are all of similar utility. Some coils are made so that the different sized ones are interchangeable on the set. They are frequently used as primary, secondary and tickler coils, the tuning adjustments being made by variable condensers.

Circuit Diagrams.—In the figures of this chapter the numbers shown on the condensers give suggested maximum values of capacity in microfarads which are correct for wave lengths of about 200 to 600 meters. Where the tuning condenser is connected across the inductance coil it is generally advisable to use a large inductance and small capacity to tune to a given wave length.

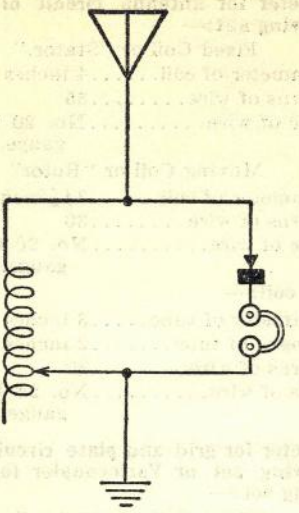


Fig. 9—Diagram of Simple Receiving Set using Crystal Detector.

Where a variable condenser (see symbols on page 33) is shown on these diagrams a condenser having a larger maximum capacity than indicated can be used, and when used with a given coil, makes it possible to tune the circuit to a wider range of wave lengths.

Fig. 9 shows a single-circuit receiving set using a crystal detector. Only one tuning adjustment is required with this set. This can be in the form of a switch or sliding contact for making connection at the desired point on the inductance coil.

Fig. 10 shows a two-circuit receiving set. The inductance coils L_1 and L_2 constitute the two coils of a coupler. There is no metallic connection between them. There are several forms of coupler: the "slide coupler," sometimes called a loose coupler, in which the coils are two cylinders wound with wire, one sliding within the other; the "variocoupler," in which one coil may be rotated within the other, and the "hinge coupler," in which the two coils are pivoted together like the two parts of a hinge.

The variable condenser C_1 is used for fine adjustment of the tuning of the secondary circuit. It is also convenient for tuning the circuit to different wave lengths. The longer the wave to which it is desired to tune the higher up one must go on the condenser scale, unless he simultaneously increases the number of turns of the inductance coil which are included in the circuit. It is usually best to use as much of the coil

as possible in tuning to a given wave length and do the close tuning with the condenser near the lower end of its scale.

The condenser C_2 is connected in series with the ground connection of the receiving set in case the antenna is somewhat longer than the ideal length for tuning to a given wave length. When connected in this way the condenser practically shortens the effective length of the antenna. The lower parts on its scale tunes the circuit to shorter waves, and when its capacity is made zero it corresponds to disconnecting the receiving set entirely from the ground.

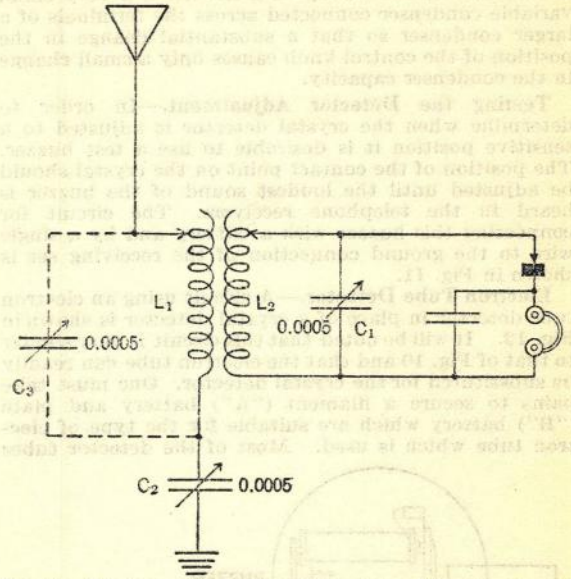


Fig. 10—Diagram of Two-Circuit Receiving Set using Crystal Detector.

In the case of a short antenna which it is desired to use in receiving from a longer-wave station the primary tuning condenser should be connected across the terminals of the inductance coil as shown by the dotted lines in Fig. 10, instead of in series with the coil. The end of the coil which is not connected to the antenna should then be connected directly to the ground. This parallel condenser gives the effect of lengthening the antenna so far as tuning is concerned and is also useful in making the final, close tuning adjustment.

The fixed condenser connected across the telephone receivers is called a "telephone condenser." Its size

is not ordinarily of much importance. Its effectiveness may depend upon the make of telephone receivers used and in some cases the use of such a condenser decreases rather than increases the strength of the received signals. Where it is useful at all a condenser of about 0.002 microfarad will usually be found quite satisfactory. It may be particularly effective in the case of reception from spark transmitting stations having low spark notes. Its utility can only be determined by trial.

The "vernier" condenser used for securing very fine adjustment of the tuning of a circuit, is a very small variable condenser connected across the terminals of a larger condenser so that a substantial change in the position of the control knob causes only a small change in the condenser capacity.

Testing the Detector Adjustment.—In order to determine when the crystal detector is adjusted to a sensitive position it is desirable to use a test buzzer. The position of the contact point on the crystal should be adjusted until the loudest sound of the buzzer is heard in the telephone receivers. The circuit for connecting this buzzer with a battery and by a single wire to the ground connection of the receiving set is shown in Fig. 11.

Electron Tube Detector.—A circuit using an electron tube detector in place of a crystal detector is shown in Fig. 12. It will be noted that this circuit is very similar to that of Fig. 10 and that the electron tube can readily be substituted for the crystal detector. One must take pains to secure a filament ("A") battery and plate ("B") battery which are suitable for the type of electron tube which is used. Most of the detector tubes

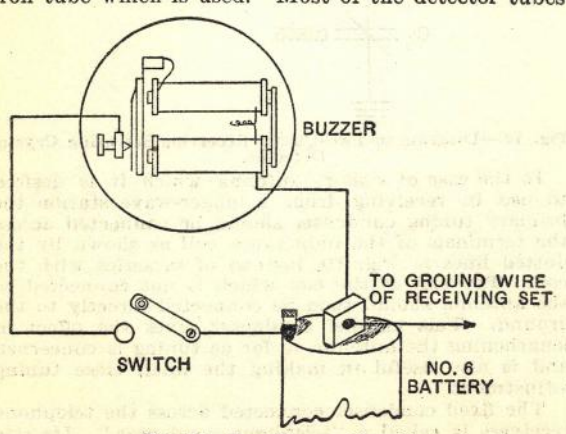


Fig. 11—Test Buzzer Circuit.

now on the market require a 6-volt storage battery and a 22½-volt plate battery. It is very desirable, however, to employ a plate battery which is adjustable by means of taps which are brought out from a number of

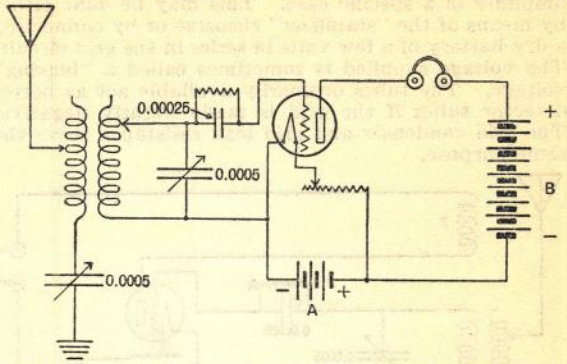


Fig. 12—Diagram of Two-Circuit Receiving Set using Electron Tube Detector.

the cells which form the complete battery. A rheostat is used in the filament battery circuit for adjusting the filament temperature to the best value.

Instead of the usual sliding contact rheostat a "ballast" lamp may be used which requires no adjustment. This is a fine wire of iron or other material enclosed in an evacuated glass tube. If the voltage of the "A" battery is slightly higher than normal, this wire tends to become heated and its resistance increased, the current thus being kept from rising to an excessive value. If the voltage of the "A" battery is below normal, the cooler wire offers less resistance, and approximately the same current is permitted to flow through the filament of the electron tube.

The connections which are made from various parts of the circuit to the filament, grid and plate of the electron tube are made by means of a socket. The wire connections can be soldered to the terminals forming a part of this base or socket, and care should be taken to make these connections to the proper terminals. A tube can be fastened into its socket by pushing it in as far as it will go and giving it a slight turn to the right. It is very desirable to use an ammeter in series with the filament and the "A" battery, in order to tell the exact amount of current which is flowing through the filament and to secure again the best adjustment when this has once been found. It is also an insurance against burning out the filament, which may result from carelessly heating the filament to an excessively high temperature by letting too much current flow through it.

It is sometimes desirable to maintain the grid of an electron tube at a definite voltage above the negative terminal of the filament, so that the tube will operate with the maximum effectiveness as a detector or as an amplifier in a specific case. This may be done either by means of the "stabilizer" rheostat or by connecting a dry battery of a few volts in series in the grid circuit. The voltage supplied is sometimes called a "biasing" voltage. The tubes ordinarily available act as better detector tubes if the grid is made slightly negative. The grid condenser and grid leak resistance serve the same purpose.

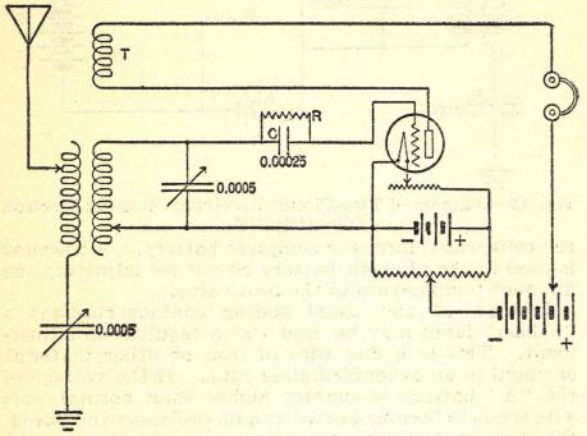


Fig. 13—Diagram of Two-Circuit Regenerative Receiving Set using Electron Tube Detector.

Tickler Coil.—Another receiving circuit using a single electron tube detector is shown in Fig. 13. This circuit makes use of a tickler coil, T, which is placed close to the secondary inductance and which is effective in increasing the loudness of the received signals. The tickler coil may be the rotor of variocoupler, or may be wound on a cylinder and so arranged as to slide within or over the secondary coil. It is also satisfactory to use flat coils, such as the "honeycomb," so arranged that the tickler coil is placed alongside the secondary coil. A small condenser C and "grid leak" resistance R are connected between the tuned circuit and the grid of the tube. A grid leak resistance of 1 or 2 megohms shunted across a condenser having a capacity of 0.00025 microfarads is ordinarily satisfactory, though the best values depend upon the particular type of detector tube employed. This circuit is very selective as well as quite sensitive and is not so likely as is the next circuit described to cause very great difficulty to nearby receiving sets by acting as a feeble transmitting set.

The resistance which is connected across the "A" battery in Fig. 13 is a potentiometer resistance or "stabilizer" of approximately 200 ohms. The sliding contact on this resistance makes it possible to obtain finer adjustment of the voltage in the plate circuit. In some circuits, as at R, in Fig. 18, a similar resistance is used to secure adjustment of the voltage between the grid and the filament. If the variations of voltage are obtained by direct connection to the individual cells of the battery it is impossible to adjust more closely than by steps of one or two volts. By using the potentiometer resistance, with its continuously variable contact, much finer variation is obtainable. This potentiometer resistance or stabilizer itself draws some current from the battery across which it is connected but the amount is small if the resistance of the potentiometer is large. This follows from the principle stated in Chap. 4 that the current is equal to the voltage divided by the resistance. It is well to entirely disconnect one end of the battery itself when the receiving set is not in use in order to avoid unnecessary waste of current.

A somewhat simpler circuit, which has the main features of that shown in Fig. 9 but which is regenerative and employs an electron tube detector and which is therefore more sensitive and selective, is shown in Fig 14. The primary inductance P and the tickler coil T may be the two windings of a variocoupler. If the set fails to regenerate or to generate, the connections to the tickler coil should be reversed, since the coupling between the tickler and the tuning inductance must be in the proper direction. If this cir-

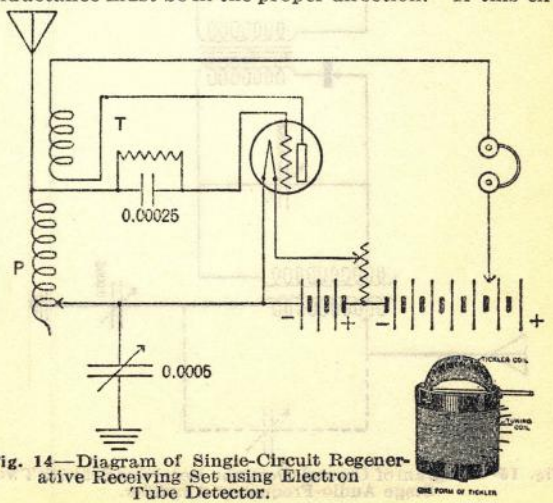


Fig. 14—Diagram of Single-Circuit Regenerative Receiving Set using Electron Tube Detector.

cuit is adjusted to the generating (oscillating) condition it may become a very troublesome source of interference to near-by receiving stations.

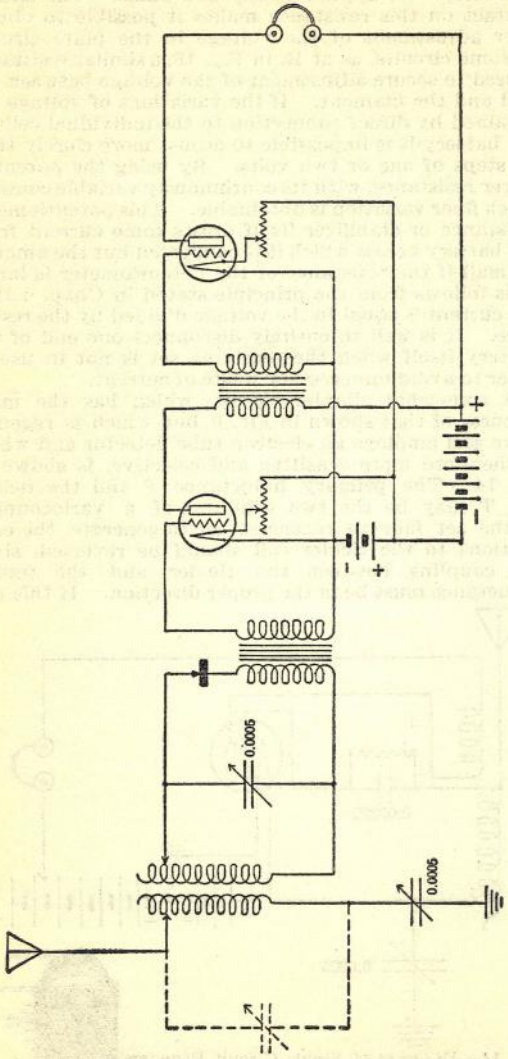


Fig. 15—Diagram of Crystal-Detector Receiving Set with Two-Stage Audio-Frequency Amplifier.

Amplifier Circuits.—A circuit which shows the method of connecting two amplifier tubes to a receiving circuit using a crystal detector is shown in Fig. 15. It is simply Fig. 10 with the telephone receivers (and their parallel condenser) replaced by the amplifier tubes and their accessories. It is more customary to use an electron tube as a detector in receiving sets having amplifiers. The use of a crystal detector, however, eliminates the cost of one tube and gives the advantage of simplicity which the crystal detector possesses.

Fig. 16 shows a set having an electron tube detector, with two amplifier tubes added. The principal change made from the circuit of Fig. 13 is the replacement of the telephone receivers by the transformer which connects to the first amplifier tube. After the desired number of amplifier tubes and intermediate transformers have been connected, the telephone receivers are then put into the plate circuit of the last amplifier tube. Unless very special precautions are taken to shield the transformers and the connecting wires of the amplifier, it is almost impossible to employ more than three amplifier tubes connected after the detector tube without causing a howling sound in the telephone receiver which makes the reception of signals impossible. In general, by placing the transformers as far as six inches apart, and placing the cores of the transformers at right angles, the trouble will be minimized. The connecting of a condenser across the terminals of the primary winding of the first transformer of an audio-frequency amplifier will sometimes increase the strength of received signals as well as reduce the likelihood of the occurrence of this "howling." A condenser having a capacity of 0.005 microfarad is suitable for this purpose.

Amplifier tubes should be used in such a way that the magnitude of the output voltage always bears the same proportion to the magnitude of the input voltage, otherwise the quality of speech or music received may be distorted. In order to secure maximum amplification with a minimum of speech distortion it is usually desirable to use, with amplifier tubes, a "B" battery of rather high voltage. It is usually better to secure this condition by adjustment of the "B" battery than by the use of a "C" battery in the grid circuit. An adjustable voltage for this purpose may be obtained by using a "stabilizer" or potentio meter resistance connected across the terminals of the filament battery. The sliding contact is connected to the part of the circuit which would otherwise connect the grid to the filament or "A" battery. Such a "stabilizer" rheostat is shown at R_1 in Fig. 18. If the input voltage to an amplifier is so great that the output voltage would be more

than the maximum which the tube could carry and still maintain the proportionality, a distortion is bound to result unless tubes of different characteristics are used. In the circuit shown in Fig. 16 a "potentiometer" resistance or "stabilizer" may be connected across the filament or "A" battery in a similar manner to that shown in Fig. 13.

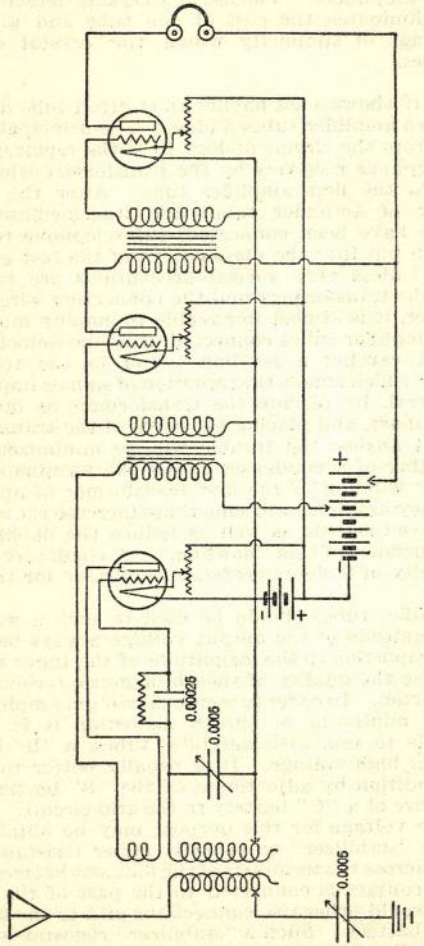


Fig. 16—Diagram of Receiving Set using Electron-Tube Detector and Two-Stage Audio-Frequency Amplifier.

The transformers used in Fig. 16 are called "audio-frequency" transformers, since they are used in the part of the circuit between the detector tube and the telephone receivers. The voltage ratio (*i. e.*, ratio of number of turns of wire in secondary to number in primary) of the audio-frequency transformers usually used is between 5 and 10. The best value of this ratio for any particular set depends both on the design of the amplifier and the characteristics of the tubes used.

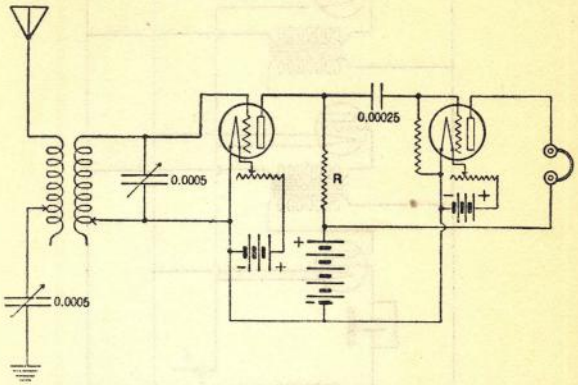


Fig. 17—Diagram of Receiving Set using Resistance-Coupled Radio-Frequency Amplifier.

In order to secure additional amplification without the undesirable howling caused by using an excessive number of audio-frequency amplifier tubes, recourse may be had to the use of a radio-frequency amplifier. The circuit connection for such an amplifier containing only a single tube is shown in Fig. 17. This circuit employs an amplifier tube which is connected between the tuned secondary circuit and the detector tube. Instead of a transformer between the amplifier and detector tubes a large resistance R (approximately 10,000 ohms) is used which is called the "coupling" resistance. This circuit operates well at the longer wave lengths, but is less efficient at the short waves than a properly constructed transformer coupled amplifier as shown in Fig. 18. Other reliable hook-ups are given in the section on "Radio-Frequency Amplifiers" on page 41 of this Chapter.

The circuit used by a six-stage radio-audio-frequency amplifier is shown in Fig. 18. The first three tubes are radio-frequency amplifier tubes; the fourth tube is a detector tube and the last two tubes are audio-frequency amplifier tubes. The same type of tube is used for both radio and audio amplification; the detector tube is of different type. In Fig. 18 the rheostat R_2 controls the current through the radio-frequency

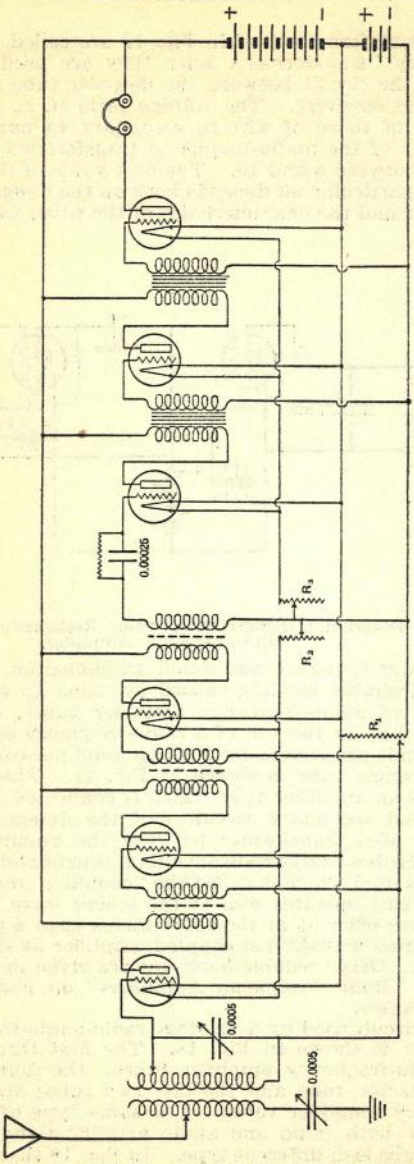


Fig. 18—Diagram of Receiving Set using Radio-Audio-Frequency Amplifier. (Using Amplifier Tubes throughout).

amplifier tubes while the rheostat R_3 controls the current through the detector and audio-frequency amplifier tubes. The transformers connected in the plate circuits of the first three tubes are radio-frequency transformers. These transformers are designed for operation over a particular band of wave lengths, and in order to secure the best results it is important that the three transformers used operate best over the same wave length range.

Radio-frequency transformers may have either an "air core," (*i. e.*, no core at all) or an iron core. The air-core transformers are efficient over a very narrow range of wave lengths but give more amplification per stage. The iron-core type gives a fairly uniform amount of amplification over a much broader range of wave lengths but does not give as much amplification per stage. A radio-frequency transformer for 360 meters can be made by winding about 200 turns of No. 44 B. & S. gauge enameled copper wire in a single layer over a core of thin laminated iron about ½ inch square and 3 or 4 inches long. A layer of some insulating material about 1/16 inch thick should be put around the iron core before the wire is wound on it. This winding can serve as the primary winding, the secondary being an identical one, wound on the same core. The inner ends of the two windings should be separated about ¼ inch from each other. In connecting these transformers to the electron tubes the inside adjacent ends of the windings should be connected to the battery circuits, the extreme outer ends being connected to the grids and plates of the tubes. Varying the number of turns of wire and the distance between these windings changes the frequency or wave length at which the transformer is most effective. The exact values best for a certain wave length can be determined by trial.

Three-Circuit Set.—The connections used in a three-circuit tuner are shown in Fig. 19. Here in addition to

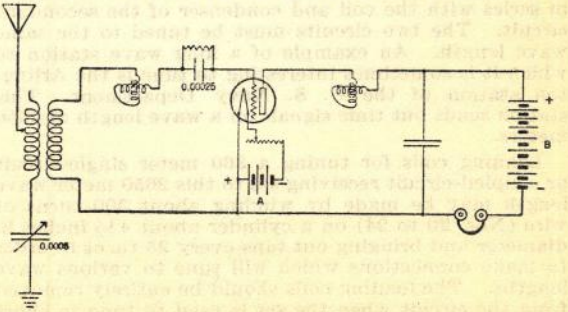


Fig. 19—Diagram of Three-Circuit Regenerative Receiving Set using Electron Tube Detector.

the primary and secondary inductance coils forming the coupler, or variocoupler, it is necessary to use two additional variable inductance coils which are usually of the form known as "variometers." These variometers are quite similar in appearance to the variocoupler, but the two windings are connected in series so that as the position of one of the coils is changed, the inductance is correspondingly varied.

This is a regenerative circuit, in which, however, the feed-back action is accomplished by the capacity between grid and plate instead of by a tickler coil. Both the plate and the grid circuit are tuned by the combination of the tube capacity with the variometer in that circuit. The condenser at the right is merely to give the radio-frequency current an easier path than it would have through the phones and battery. Since the amount of feed-back can not be varied directly, as it can be in regenerative sets employing a tickler coil, this type of set is very difficult to adjust (see page 11). Any change of setting of the coupler coupling or of either variometer varies the adjustment of the others. It rewards patience by giving loud signals, but is troublesome to operate.

It is necessary to provide for fine adjustment of the antenna wave length, either by strictly continuous variations of the inductance in series with the antenna or by the series condenser. If the series condenser is not used, because of receiving longer waves, the condenser may be placed in parallel with the antenna inductance coil and serve as fine adjustment of it.

Loading Coils for Long Waves.—Single-circuit and coupled-circuit receiving sets which are designed for short-wave reception may be modified for use in receiving signals from longer wave stations by the addition of loading coils. In the single-circuit set this loading coil is connected in series in the antenna lead wire. In the coupled circuit set one loading coil is connected in the antenna circuit and another similar one is connected in series with the coil and condenser of the secondary circuit. The two circuits must be tuned to the same wave length. An example of a long wave station to which it is sometimes interesting to tune is the Arlington station of the U. S. Navy Department. This station sends out time signals on a wave length of 2650 meters.

Loading coils for tuning a 360 meter single-circuit or coupled-circuit receiving set to this 2650 meter wave length may be made by winding about 300 turns of wire (Nos. 20 to 24) on a cylinder about 4½ inches in diameter and bringing out taps every 25 turns in order to make connections which will tune to various wave lengths. The loading coils should be entirely removed from the circuit when the set is used to tune to short wave lengths since they greatly decrease the efficiency

of the set by introducing capacities which result in power loss. Even when tuned to receive long-wave signals, a loaded set is not as efficient as one which is originally made according to the proper design for this use. Nevertheless the use of a loading coil to extend the wave length range of a short wave set is thoroughly practicable; the long wave stations which it is desired to hear are usually of higher power than the short wave stations and can therefore be easily heard. It is not practicable to attempt to load a three-circuit tuner to receive signals of longer waves than those for which it is designed.

Accessories.—For use in constructing or assembling receiving sets, there are several accessory parts which are required, but which can be readily purchased from almost any dealer in electrical supplies. These include binding posts, rotary lever switches, battery switches, knobs, dials, wire, buzzer, cardboard tubing, panel parts, etc. The requirements as to numbers and sizes and other particulars are dependent upon the circuit which it is desired to follow.

Series and Parallel Condensers.—The series condenser shown in the antenna circuit of Figs. 10, 12, 13, 14, 16, 17, 18, 19 is not necessary if the antenna is short enough to enable one to tune to the desired wave length by the adjustment of the series inductance coil. The shorter the wave, the lower will be the setting of the series condenser. If the desired wave length is longer than that to which the series inductance makes it possible to tune, the wave length of the antenna circuit may be increased somewhat by connecting the condenser across the terminals of the series inductance. This condenser can conveniently be a variable condenser having a maximum capacity of 0.0005 microfarad. Either the series or the parallel condenser serve the added purpose of enabling one to tune more closely to the wave length desired by making finer adjustment of the tuning of the circuit than may be obtained by varying the number of turns of the coil only.

Construction Details of Receiving Sets.—When a receiving set is assembled in a box it is desirable to use a sheet of metal as a lining of the front panel in order to reduce the effect of the hand of the operator on the capacity between the parts of the set. This shield should be connected to the negative terminal of the filament or "A" battery or else to the ground terminal of the receiving set.

In assembling a receiving set all connecting wires should be as short as possible and should run in as nearly straight lines as is consistent with keeping them spaced well apart from one another. The size of the connecting wires is not especially important though it should not be extremely small. Wire of any size between No. 26 and No. 14 B. & S. gauge is satisfactory

though slight preference should be given to the heavier wire.

In theory it would be desirable in winding coils and in wiring up radio sets to use wire having many fine strands insulated from one another and woven together in the form of a cable. Such a conductor is called "litzendraht," or "litz," or "high frequency cable" and would be expected to have a lower resistance to radio currents than solid wire of the same weight. Since the insulation can not be infinitely thin, however, it turns out that for very short waves solid wire is better than any actual stranded wire. Practically, moreover, it is difficult to insure that the fine strands are continuous and not broken and that they are all completely insulated from one another. It is not easy to make a soldered connection to all of the strands forming such a cable. It is, therefore, usually not worth while to use other than solid copper wire in the construction and assembly of ordinary radio receiving apparatus.

Some of the variometers and variocouplers on the market employ the shaft as a connection to one side of the rotating ball or coil. If this type of variometer is purchased it should be seen that the shaft end which projects through the shielding panel is at the grounded end of the circuit. In the case of the variocoupler it is usually better not to use the shaft as a connection. Direct flexible connections should be made to the coils and the shaft should be grounded to the shield.

Sometimes inductance coils are used which have a very large number of turns, only a few of which are used for tuning to short wave signals. It is best in such a case to have a switch called a "dead-end" switch for entirely disconnecting the major part of the coil when not in use. This decreases the loss of power in the unused portion of the coil.

When a coil of many turns is wound in the ordinary way in several layers the distributed capacity is made larger than if the same wire were wound in a single layer. The objectionable length of a single layer coil is avoided and the advantage of low distributed capacity is partly retained by coils wound with a basket form of winding. In such coils there is a considerable air space between the wires. This method of winding often makes the coils self supporting.

It is desirable to have as little solid dielectric as possible in the region immediately surrounding the wires of an inductance coil. The existence of solid insulation results in the loss of power and the decrease of signal strength. Even the enamel or silk insulation on wire is a cause of loss of power though of course the adjacent turns on a coil must be kept out of metallic contact with one another. Cotton insulation is better on this account and it is also less expensive. No

shellac should be used for the coating or impregnation of coils on account of the power loss which it causes.

On variometers where the scale is not fixed in position on the shaft, the dial should be made to indicate the minimum or zero position when the coils are in such a position that the current flows in opposite directions in the two coils.

Provision should be made for disconnecting both the "A" and the "B" batteries from the set when not in use, in order that they may not needlessly become discharged.

A grid leak resistance may be made by drawing a rather heavy line with a soft pencil on a piece of card board about 1½ inches long and connecting it across the terminals of the grid condenser. The best adjustment of this resistance can be determined by trial by widening it or by narrowing the line by erasure.

How to Remedy Receiving Circuit Troubles.—Receiving sets like other electrical apparatus may suffer from short circuits or open circuits. An open circuit often makes itself known by a low pitched hum in the telephone receivers. A simple way of testing for this trouble is by the use of a telephone receiver and dry cell. On account of the small distance which is allowed between the fixed and moving plates of the variable condensers it is possible for these condensers to become short circuited at certain positions on the scale. The telephone receiver and battery may also be used for locating this trouble. It may be remedied by giving the bent plate a slight push with a screw driver while care is taken to avoid bending the adjacent condenser plates. In some condensers the position of the shaft carrying the movable plates is adjustable and may be changed by means of nuts located on the base of the condenser. Sometimes the telephone receiver cord becomes defective. This is noted by a rasping or scratching sound or a click when the telephone cord is moved. A new telephone cord can be obtained for a small sum from any radio supply store. In a regenerative receiver if the adjustment of the grid and plate variometers or the tickler coil fails to produce regeneration, the filament current and plate voltage should be changed. If the filament of an electron tube fails to light or flickers, the tube should be removed from its socket and the ends of its four contact prongs should be cleaned with sandpaper or a fine file. It should be made certain that the spring connections in the tube socket make good contact with the prongs on the tube. It is desirable to try various combinations of the tubes used as detector and amplifier tubes since it is possible to find a best arrangement of these tubes in the various parts of the circuit. When the filament of an electron tube is burned out there is no remedy other than to replace the tube by a

new one. Repaired tubes are not likely to be satisfactory unless as great care is taken with the repairing as is required in manufacturing. It is especially difficult to be sure that the vacuum will hold.

Noises.—Grinding noises which persist when the antenna and ground wires are disconnected from the receiving set are not caused by atmospherics or "static" but may usually be remedied by tightening the connections to the binding posts at various parts of the circuit, by cleaning the contacts of the tubes, or by replacing old "B" batteries by new ones. Sometimes an electron tube is found which has a poor connection between the filament itself and the lead wire, which connects the filament with the prong on the base. Such a tube should be removed from the circuit and replaced by a new one.

Interference from Radio Stations.—Interference from undesired radio stations or from atmospheric electricity is obtained only when the antenna and ground wires are connected to the receiving set. The interference from spark stations can be recognized by the long and short buzzing sounds constituting the dots and dashes of the radio telegraph code. Such stations may be either commercial radio stations, such as operate between ship and shore or may be amateur spark stations. Such interference can be minimized by reducing or loosening the coupling between the primary and secondary circuits or by reducing the tickler or regenerating action of the receiving set. Interference from continuous wave transmitting stations or from nearby receiving stations which are so adjusted as to act as weak transmitters is recognized by a whistling sound or continuous musical note. If it is found that the pitch of this musical note changes as the receiving set is detuned, this is an indication that the receiving set at hand is also generating and acting as a feeble transmitter. The tickler or regenerating action should therefore be reduced. When the adjustment passes this generating point a click will be heard in the telephone receivers.

Sometimes it is noticed that the strength of the signals received from distant stations varies rapidly for no apparent cause. This is particularly true at night when the signals may fade in and out regularly or irregularly. While it is advisable to make sure that the connections to the receiving antenna are not loose, this difficulty is usually caused by changes in the condition of the space through which the radio waves travel between the transmitting and receiving stations. This difficulty is therefore obviously entirely out of the control of the receiving set manufacturer or user.

Weak Signals.—If the signals which are customarily loud from a station are suddenly found to be quite

SYMBOLS USED IN DIAGRAMS


Fixed Condenser


Variable Condenser


Crystal Detector


Ground


Battery


Grid Condenser and Grid Leak


Variometer

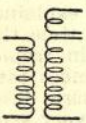

Phone

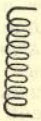

Antenna


Electron Tube


Audio-Frequency Transformer


Radio-Frequency Transformer


Coupled Inductance with Tickler Coil


Inductance Coil

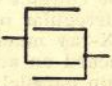

Wires Join


Wires Do Not Join


Chopper


Inductance with Iron Core


Variable Coupling of Coils


Transmitting Condenser


Resistance

weak, the difficulty may be caused by one or more of the following:

a. The transmitting station may have reduced its power.

b. The crystal detector of the receiving set may be out of adjustment or may have become dirty. In the latter case the metal point which touches the crystal may be filed and the surface of the crystal washed with soap and water. Care should be taken not to touch the surface of the crystal with the fingers.

c. The receiving antenna may have become disconnected or may have fallen from its supports.

d. The ground connection may have become disconnected or the water may have been drawn from the system or water pipes which are used for grounding the set. In the latter case the existence of insulating paint or gaskets may have resulted in making the ground connection ineffective. For further comments on ground connections, see chapter 3.

e. The plate battery may be exhausted.

f. The filament battery may have become discharged.

g. The telephone plug may not be making good contact either by its being pushed too far or else not far enough into the receiving set.

Atmospheric Interference.—Irregular interfering noises heard in the telephone receivers are often caused by atmospheric electricity. These disturbances are variously called "strays," "static," "atmospheric," "atmospheric disturbances," and other names. There are probably many causes for these stray waves, but their sources have never been completely explained. They are more troublesome in the summer time then in the winter and are also more serious in tropical latitudes than in northern regions. The most satisfactory methods of reducing this atmospheric interference are the use of small antennas with very sensitive amplifiers and the use of very loosely coupled circuits. Radio telephony has an advantage over radio telegraphy when it is necessary to receive through this type of interference, since speech can often be understood by context even though some parts of it are lost. Some sources of interference which produce sounds very similar to atmospherics are the leaking of electric currents over the surface of faulty insulators of power lines, the sparking at commutators of electric motors, sparking at the contact of trolley wheels with the trolley wires, the irregular operation of arc lights and the operation of X-ray machines. In some cases a continuous hum is heard on account of the antenna or ground wire being run parallel to an electric light or power circuit. This can be reduced by moving the antenna to a position at right angles to the power line. When it is desired to use a receiving station for continuous reliable reception of any radio service, it is advisable to investigate the possibility of such causes of interference in the immediate neighborhood as have just been mentioned.

Automatic Filament Control.—Fig. 20 shows an arrangement by which the electron tubes are automatically lighted as needed. Insertion of the telephone receiver plug in any jack causes the needed tubes to light up, and the needed tubes only. That is, when the phone plug is inserted in jack 3 all three tubes light up; when in jack 2 only the detector tube and first audio-frequency amplifier tube light up; and when in jack 1 only the detector tube is lighted. Removing the

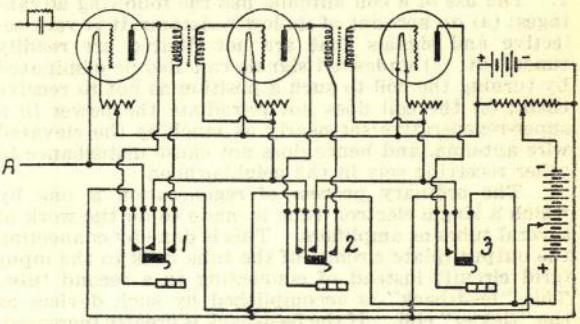


Fig. 20—Connections to Jacks for Automatic Filament Control of Detector and Two Stages of Audio-Frequency Amplification.

phone plug automatically stops the drain on the filament battery. If radio-frequency stages (not shown in figure) are used, they will be lighted up by insertion of the phone plug in any jack, provided the filaments of the radio-frequency tubes are connected to the point A and to the positive end of the filament battery (either direct or through a potentiometer resistance).

Super-Regenerative Radio Reception—While this advance is based upon a simple principle, anyone who attempts to understand or to use it should have some knowledge of electron tubes as detectors, amplifiers, and generators; of regenerative reception and of coil antennas. The reader is particularly advised to be familiar with the explanation of regeneration in Chap. 5, page 9, and the operation of regenerative receiving sets, Chap. 2, pages 12 and 20. Super-regenerative apparatus is not yet on sale; it probably will be after commercial development by the companies which control the patents on regeneration.

This new method obtains results of the same order as those obtained with good radio-frequency amplifiers

(see Chap. 2, page 25, and Chap. 6, page 4), and does it with fewer electron tubes. It is particularly suitable for amplifying loud signals, but has not been very successful for weak signals from distant stations becasue of noises produced within the apparatus. It makes a receiving set so sensitive that signals from distant stations may be received as loud as desired without an outdoor antenna. Information on the small indoor antennas which may be used with a super-regenerative receiving set is given in Chap. 3, pages 7 to 11, and Chap. 6, page 1. The use of a coil antenna has the following advantages: (*a*) on account of its low resistance it is very selective and signals that are not desired are readily tuned out; (*b*) undesired signals can also be eliminated by turning the coil to such a position as not to receive them; (*c*) the coil does not re-radiate the power in a super-regenerative set nearly as much as the elevated wire antenna, and hence does not cause disturbance in other receiving sets in the neighborhood.

The ordinary process of regeneration is one by which a single electron tube is made to do the work of several tubes as amplifiers. This is done by connecting the output (plate circuit) of the tube back to the input (grid circuit) instead of connecting to a second tube. This "feed-back" is accomplished by such devices as the "tickler" coil. If the feed-back is greatly increased, as by increasing the tickler coil coupling, the electron tube becomes a generator (as explained on page 12, Chap. 5), and hissing or sharp rumbling noises are heard in the phone instead of the desired signals. The sensitiveness of the electron tube as an amplifier increases as the feed-back coupling is increased up to this point of self-generation ("oscillation") which spoils the incoming signals. This self-generation has therefore been the limit to which the feed-back process could be carried.

Super-regenerative reception is a method whereby the feed-back or regenerative process can be carried much farther than the limit heretofore imposed by self-generation. It depends on the fact that self-generation does not take place instantaneously but requires time for the generated current to build up to its final value. The feed-back is made sufficiently great so that self-generation would normally take place, but after a brief instant the feed-back is reduced so that the self-generated current dies out. The feed-back is made to alternate repeatedly above and below the value required for self-generation. During the time that it is above this value, the current in the tube builds up rapidly and to a much larger amount than with ordinary regeneration, and during the intervals when it is below this value the current practically dies out. The alternation in the feed-back is made to take place at a rate so rapid as not to interfere with the signal.

Super-regeneration is accomplished by introducing in the ordinary regenerative circuits anything which periodically varies the feed-back above and below the point required for self-generation. The voltage which the tickler coil feeds back into the grid circuit depends upon the direct voltage existing in the plate circuit. Super-regeneration may therefore be brought about by introducing some form of alternating current generator (G, Fig. 21) in series with the B battery.

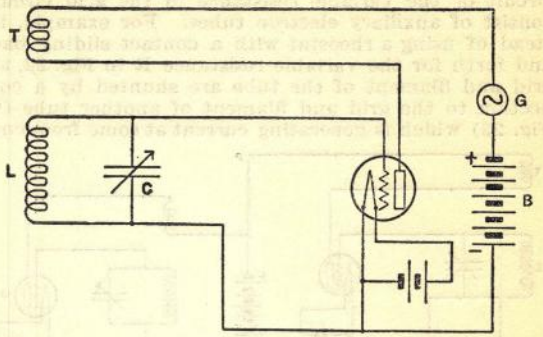


Fig. 21—Periodic variation of feed-back voltage.

When the voltage in this generator is in the same direction as the voltage from the battery, the feed-back increases beyond the point of self-generation and the current builds up to a very large value; when the voltage reverses the current dies out.

The same thing can be accomplished in another way. The value of the feed-back is affected by the resistance in the tuned circuit (C L) connected to the grid. If the tickler coil is adjusted so as to be almost on the point

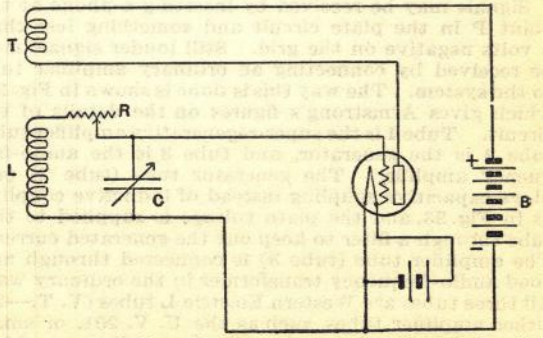


Fig. 22—Periodic variation of resistance of tuned circuit.

for self-generation, a reduction of the resistance of the tuned circuit will start the current building up to a very large value. If the resistance is then increased again the current will die out. Super-regeneration is thus accomplished by introducing in the tuned circuit (C L, Fig. 22) a resistance (R) which is made to vary periodically.

The actual means that have been used to produce super-regeneration, either the generator in the plate circuit or the variable resistance in the grid circuit, consist of auxiliary electron tubes. For example, instead of using a rheostat with a contact sliding back and forth for the variable resistance R in Fig. 22, the grid and filament of the tube are shunted by a connection to the grid and filament of another tube (G, Fig. 23) which is generating current at some frequency

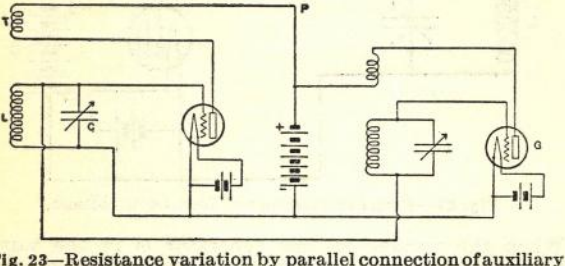


Fig. 23—Resistance variation by parallel connection of auxiliary generating tube.

lower than the received radio frequency. During one-half of the cycle of current generated by the auxiliary tube G, it draws current from the tuned circuit C L, thus having the same effect as increasing the resistance of C L. The resistance thus rises and falls periodically at the frequency of the current generated by the auxiliary tube G.

Signals may be received by inserting a phone at the point P in the plate circuit and something less than 5 volts negative on the grid. Still louder signals may be received by connecting an ordinary amplifier tube to the system. The way this is done is shown in Fig. 24, which gives Armstrong's figures on the details of the circuit. Tube 1 is the super-regenerative amplifier tube, tube 2 is the generator, and tube 3 is the audio-frequency amplifier. The generator tube (tube 2) employs capacitive coupling instead of inductive coupling as in Fig. 23, and the plate voltage is supplied to this tube through a filter to keep out the generated current. The amplifier tube (tube 3) is connected through any good audio-frequency transformer in the ordinary way. All three tubes are Western Electric L tubes (V. T.—2). Other amplifier tubes, such as the U. V. 201, or small power tubes, may be used, with plate voltages as high

as the tubes will stand. Power tubes are preferable. All tubes must be of the same type but need not be matched. The various coils, condensers, batteries, and other parts are the standard types used in radio apparatus. The condensers marked 0.0025 and 0.005 are set once for all for a frequency of about 15,000 cycles per second.

Operation is as follows: Signals are tuned in by varying the 0.001 condenser in the Tube 1 circuits. The 0.001 condenser in the Tube 2 circuit is then adjusted for loudest signal. The 0.001 condenser in the Tube 1 circuits is then adjusted once more for loudest signal. Both directions of the connection to the filament battery should be tried, as the signals will be much better with one connection than the opposite. The operator should not be discouraged if results are not obtained immediately. It should be remembered that it took Armstrong six months to get the results.

The super-regenerative method may be used in a great variety of forms. The functions of super-regenerative amplification, generation, and detection may each be performed in separate tubes; they may be combined in various ways, or all functions may even be combined in a single tube. When the whole thing is done in a single tube it is very complicated to operate.

The three-tube arrangement is by far the easiest one to tune and for this reason only the circuit diagram of the three-tube set is given. In the other arrangements the various tuning adjustments affect one another.

This method may be used to receive any kind of radio signals, telephonic or telegraphic. It constitutes a new and independent method for receiving "continuous-wave" signals. When receiving such signals, the frequency generated in the set for periodically varying the feed-back, called the "variation frequency" is a low audible frequency. In Fig. 24, which is for radiophone reception, the variation frequency is 15,000, so as to be inaudible and not disturb the sounds received. It is best to keep the variation frequency as low as possible, because the lower this frequency the more time there is for the incoming current to build up. The sensitiveness of the method is proportional to the ratio of the wave frequency to the variation frequency. For this reason it is very well adapted to short waves, and will probably be valuable in extending the use of waves much shorter than any now in use.

Notes

Variocoupler must have at least 50 turns on secondary.

Either duolateral or honey-comb coils may be used for the 1250 and 1500 turn inductance. These coils should be kept apart and be mounted at right angles.

"B" battery of less than 200 volts may be used but results will not be as good.

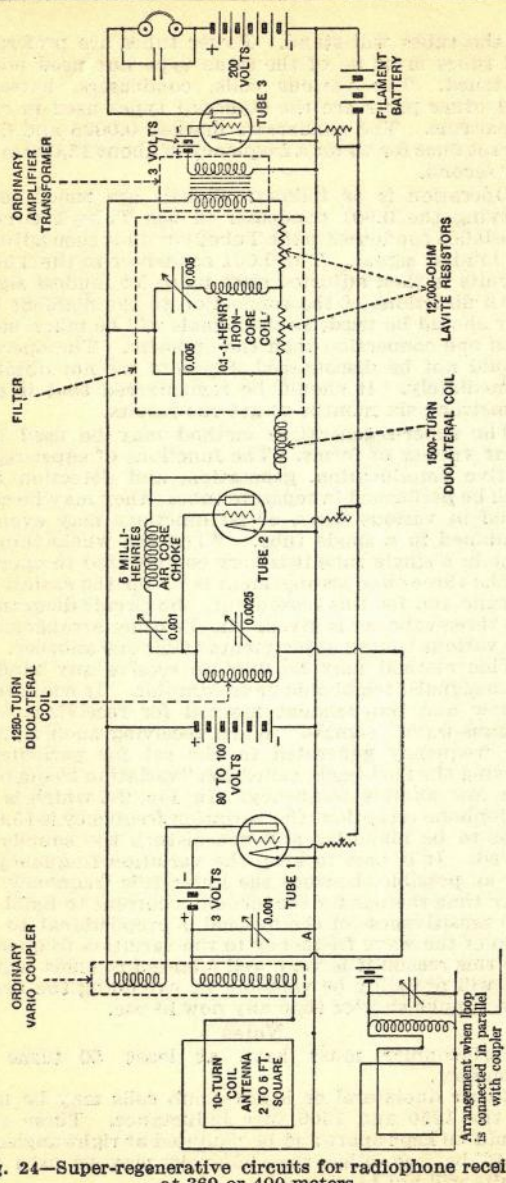


Fig. 24—Super-regenerative circuits for radiophone receiving at 360 or 400 meters.

The 80-100 volt battery need not be variable.

While a 200-volt battery is shown at the right of Fig. 24, this can utilize in part the "80 to 100 volt" battery to the left, so that only a 100-volt additional battery need be provided; this is done by breaking the connection shown at negative end of right-hand battery and running instead a connection from negative end of right-hand battery to positive end of "80 to 100-volt battery."

The 12,000 ohm resistors are non-inductive, this however, is not necessary, Grid leaks of proper value will function equally well. These resistors need not be variable and a tolerance of several thousand ohms is permissible.

The 5-millihenry air-core choke can be either closely wound or spread out but is preferably of the former type.

The same number of turns are used for a 2-ft. loop as for a 5-ft loop. Because of the variable value of inductance in standard variocouplers it is necessary to try connecting the loop both in series and in parallel with the primary of coupler as shown in Fig. 24. Adopt the connection which enables you to tune within the range of the variable condenser 0.001. If this is impossible with either connection, then reduce the number of turns on coil antenna until the desired result is obtained.

It is immaterial whether the grid tap "A" be as shown or tapered into filament rheostat.

Generally speaking, run plate voltage as high as tubes will allow.

No special points need be observed in wiring this set beyond those given on page 29 of Chap. 2.

Radio-Frequency Amplifiers—The following information supplements that given previously in this chapter in connection with Figs. 17 and 18, and in Chap. 6, page 4. Particular attention is invited to Figs. 28 and 29, which show how to combine radio-frequency amplification and regeneration. This is a development of great importance, because the ordinary regenerative set does not have radio-frequency amplification between the antenna and the regenerative tube and consequently acts as a transmitting station when in the generating condition and gives rise to the objectionable interference that has become so common.

One of the best ways to secure loud signals from nearby radio stations or satisfactory reception from distant stations is by employing radio-frequency amplification. By this method the radio-frequency current of a receiving antenna is amplified before it reaches the detector. It is then converted into current of a lower or audible frequency, which is made, either directly or through an audio-frequency amplifier, to operate the telephone receivers or loud-speaking reproducer.

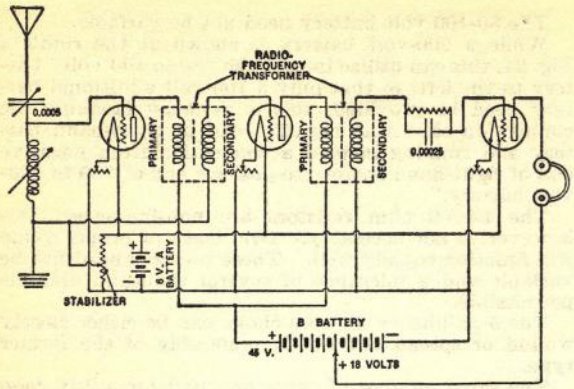


Fig. 25—Two-Stage Radio-Frequency Amplifiers and Electron Tube Detector.

Radio-frequency amplification and regeneration can be combined in the same circuit, thus obtaining the sharpness of tuning which is characteristic of the latter. Two circuits by which this is accomplished are shown in Figs. 28 and 29.

The radio-frequency amplifier ordinarily consists of several electron tubes connected successively through radio-frequency transformers. The circuit given in Fig. 18, page 26 of Chapter 2, shows the connections of a receiving set which employs both radio-frequency and audio-frequency amplification. The first three transformers shown in that circuit are radio-frequency transformers and should be such as to give greatest amplification at the wave length of the signals from the desired station; for example, 360 meters (833 kilocycles per second). These transformers may either be purchased or may, with some experimenting, be constructed by the user. A description of the construction of an iron-core radio-frequency transformer is given on page 27 of Chapter 2. Air-core transformers, when properly made

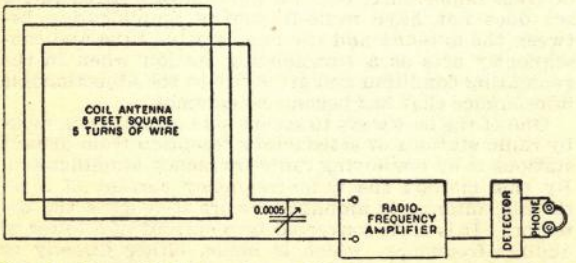


Fig. 26—Essential Connections of Radio-Frequency Amplifier Set Using Coil Antenna.

and used, give greater amplification but are limited in their usefulness to a narrower band of wave lengths.

The two windings or coils of an air-core radio-frequency transformer are usually identical in construction. A suitable design is as follows: Wind about 300 turns of No. 38 B & S. gauge single silk covered copper wire in a form having an inside diameter of 1¼ inches, and a thickness of 3-32 inch. If this coil is wound in the so-called "basket" or "honeycomb" style, the distributed capacity of the coil will be kept low. This is an advantage.

The two similar coils forming the two windings of the transformer should be mounted coaxial and parallel to each other and about half an inch apart. The wave length to which the transformer is tuned can be increased somewhat by moving the coils closer together. The wave length may be decreased by separating the coils slightly or by removing some of the turns of wire.

The stabilizer rheostat, R_3, of Fig. 18 (page 26 of Chapter 2) makes possible the adjustment of the voltage of the grids of the radio-frquency amplifier tubes to give a minimum of distortion. Care must be taken to keep this adjustment below the point where the circuit "oscillates" or becomes a generator of radio-frequency current. In the latter case a hissing or a whistling sound is usually heard which seriously interferes with the received signals.

A somewhat simpler circuit is that shown in Fig. 25, which includes two radio-frequency amplifier tubes and a detector tube. In place of the telephone receivers connection may be made to an audio-frequency amplifier. In this figure the antenna is shown connected to a single-circuit tuner. The connection to a coil antenna is shown in Fig. 26. The amplifier may be any one of those shown in Figs. 17 or 18 of Chapter 2 (pages 25 and 26) or Fig. 25.

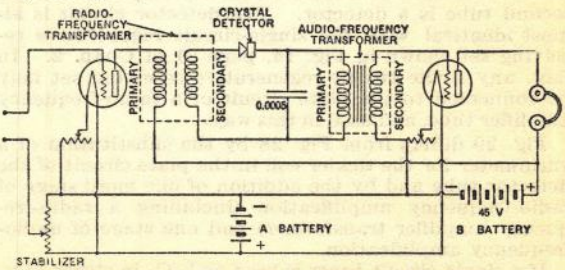


Fig. 27—Amplifier Consisting of One Stage of Radio-Frequency Amplification, a Crystal Detector, and One Stage of Audio-Frequency Amplification.

It is possible to use a crystal detector in place of the electron tube detector in a multi-stage amplifier. In this case the circuit shown in Fig. 27 may be used.

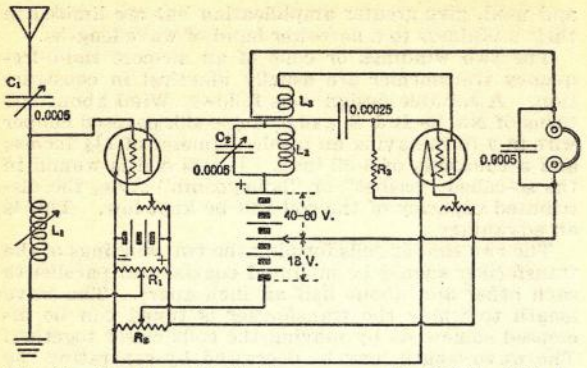


Fig. 28—One-Stage Radio-Frequency with Tickler Coil for Regeneration.

While this diagram shows only one stage of radio-frequency amplification and one stage of audio-frequency amplification, it is possible to use either two or three stages of either, employing connections similar to those in the other diagrams referred to above.

The ordinary radio-frequency amplifier circuit is not capable of such sharp tuning and is not so selective as a well-designed regenerative receiving circuit. This is particularly true when a direct connection is made to the tuning inductance in the antenna circuit as shown in Fig. 25, rather than by the use of coupled circuits as in Fig. 18, page 26 of Chap. 2. The circuit shown in Fig. 28 employs two tuned circuits and, in addition, has a feed-back or tickler coil which is used both to increase the strength of the received signals and to sharpen the tuning of the second resonant or tuned circuit. The first tube is used as a radio-frequency amplifier and the second tube is a detector. The detector circuit is almost identical with the single-circuit regenerative receiving set shown in Fig. 14, page 21 of Chap. 2. In fact, any single circuit regenerative receiving set may be connected to the plate circuit of a radio-frequency amplifier tube, and used in this way.

Fig. 29 differs from Fig. 28 by the substitution of a variometer for the tickler coil in the plate circuit of the detector tube and by the addition of one more stage of radio-frequency amplification (including a radio-frequency amplifier transformer) and one stage of audio-frequency amplification.

If a single circuit tuner is used as L_2C_2 in either Figs. 28 or 29, it is necessary to make sure that the coil and condenser are in parallel with one another. A tuner having the coil and condenser connected in series can be used by connecting the antenna and ground terminals together for one terminal and bringing out a special con-

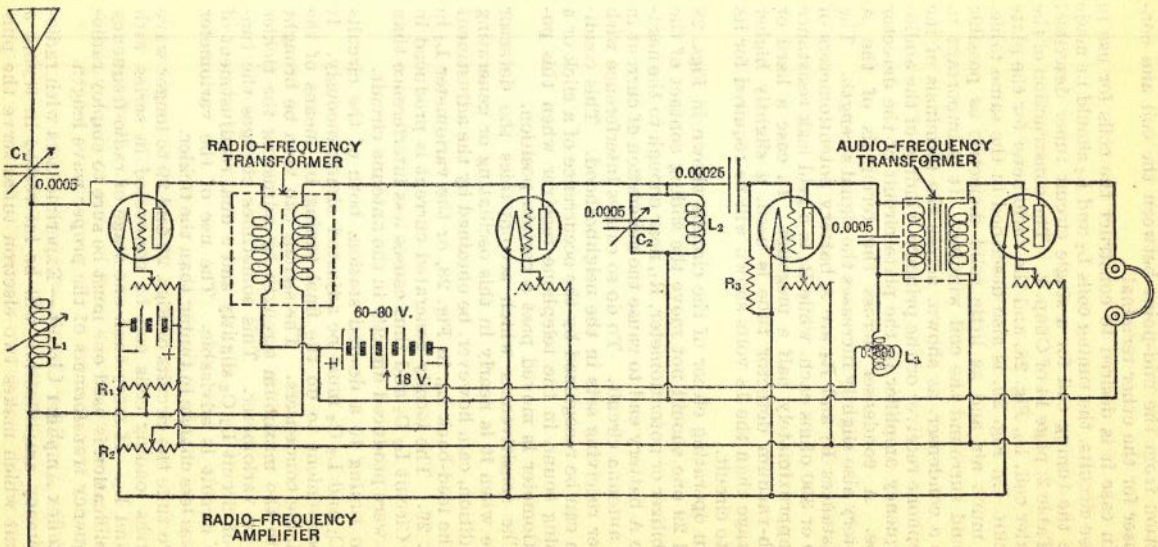


Fig. 29—Two-Stage Radio-Frequency and One-Stage Audio-Frequency with Variometer for Regeneration

nection from the mid-point between the coil and condenser for the other terminal.

In case it is desired to construct the coils for use in these circuits, the tuning coils L_1 and L_2 should be made like the tuning coil for a single circuit tuner described in Table 2, page 14 of Chap. 2. The construction of the tickler coil, L_3, Fig. 28, and the variometer for the plate circuit, L_3, Fig. 29, is also described in the same table. As much air and as little solid dielectric as possible should surround the coil winding. It is important to use a condenser, as shown, across the terminals of the telephone receiver or the primary winding of the audio-frequency amplifier in the plate circuit of the detector tube. A condenser across the terminals of the A battery also slightly increases the signal strength. The resistances R_1 and R_2 are A battery potentiometers of 200 or 300 ohms each, while R_3 is a grid leak resistance of approximately half a megohm. In case a hard or high-vacuum detector tube is used, a slightly higher voltage than the 18 volts shown will be required for its plate circuit.

In operating either of the circuits shown in Figs. 28 and 29 one should not move the sliding contact of the stabilizer or potentiometer, R_1, near enough to the negative A battery end to cause the generation of current in the antenna circuit. To do so causes interference with other receiving sets in the neighborhood. This condition can be recognized by the occurrence of a click or a hissing sound in the telephone receiver when this potentiometer is moved past a certain position.

The sensitiveness which accompanies the detector tube when it is nearly in this oscillating or generating condition, can, however, be obtained by the adjustment of the feed-back L_3, in Fig. 28, or the variometer L_3 in Fig. 29. The locally generated current is produced in the Circuit L_2 C_2 and thus causes less interference than if it were produced directly in the antenna circuit.

In tuning to a desired station, both of the circuits L_1 C_1 and L_2 C_2 must be adjusted simultaneously. It is convenient to do the final tuning by means of the variable condensers. The signals can then be brought up to the maximum strength by adjusting the tickler coil or variometer. This sometimes changes the tuning of circuit L_2 C_2 slightly and a final readjustment of this circuit is advisable. The use of the variometer causes less change in tuning than the tickler.

To tune the circuits of Figs. 28 and 29 to longer wave lengths loading coils can be connected in series with L_1 and L_2. If more than one stage of radio-frequency amplification is used one must be sure to employ radio-frequency transformers of the proper wave length.

Reflex Amplifier Circuit.—Experimenters with radio-frequency amplification will be interested in trying a circuit which makes two electron tubes serve the pur-

poses ordinarily requiring three tubes. To accomplish this the first tube of the amplifier circuit is used both as a radio-frequency amplifier and as an audio-frequency amplifier. A circuit which can be used to accomplish this is shown in the diagram below (Fig. 30). It will be seen that the radio-frequency current in the receiving antenna is amplified by the first electron tube. The second tube serves as a detector, but in place of the telephone receivers or a connection to additional audio-frequency amplifier tubes, a return connection is made to the input terminals of the first radio-frequency amplifier tube.

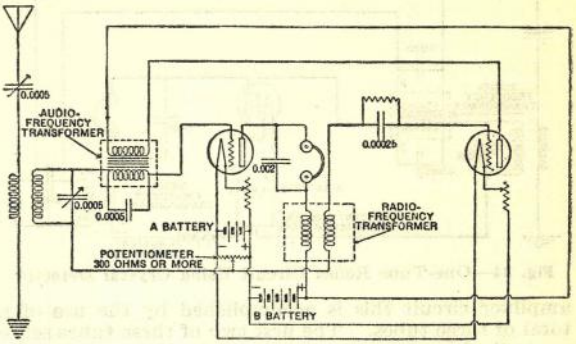


Fig. 30—Two-Tube Reflex Circuit.

The audio-frequency current from the detector tube is thus amplified by the first tube which is simultaneously amplifying the original radio-frequency current. In the plate circuit of the first tube is a connection to the telephone receivers. The telephones do not respond to the radio-frequency current originally passing through the tube, but are affected only by the audio-frequency current which has been brought back to this tube from the detector.

The factors to consider in operating this type of circuit are the necessity of simple wiring and orderly arrangement of the circuit elements. The position of the sliding contact on the stabilizer rheostat is likely also to be important.

In Fig. 30 both tubes are of the amplifier type and the B battery is of 45 volts or more. The tuning equipment is an ordinary variocoupler, specifications for which can be found on page 15 of Chap. 2. A 200-ohm potentiometer will be satisfactory if one of higher resistance cannot be procured. Dry battery tubes can be used in this circuit if desired. A soft tube may be used for the detector if a tap is taken from the B battery to supply its plate with 22½ volts instead of 45 as shown.

A reflex amplifier can be made from a single electron tube and a crystal detector; the single tube serves both as a radio-frequency and as an audio-frequency amplifier. The crystal detector serves the same function as the tube detector shown in Fig. 30. The circuit employing a crystal detector and a single amplifier tube is given in Fig. 31.

If it is desired to have sufficient amplification to operate a loud speaker it is usually necessary to have two stages of audio-frequency amplification. With a reflex

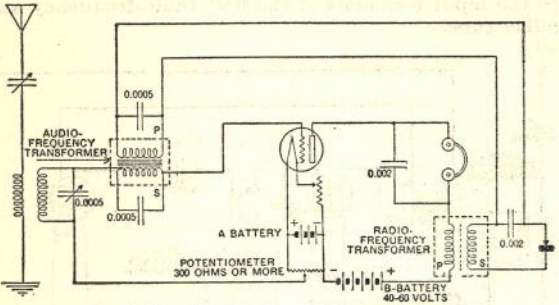


Fig. 31—One-Tube Reflex Circuit Using Crystal Detector

amplifier circuit this is accomplished by the use of a total of three tubes. The first two of these tubes serve as radio-frequency amplifiers and also as audio-frequency amplifiers. The third tube is the detector tube. A reflex circuit using three tubes in this way is shown in Fig. 32. If amplifier tubes are used in all three stages, the B battery voltage should be between forty and sixty-volts. If a soft tube is used as a detector tube, the connection to its plate circuit should be made from the twenty-two volt tap on the B battery. The antenna and secondary inductance coils are the primary and secondary respectively of a variocoupler; or in place of a coupled circuit it is entirely feasible to use a single-circuit tuner. The details of the sizes of coils used in either case are given in Table 2, of this chapter.

If the circuit tends to howl or "oscillate" this can sometimes be stopped by the insertion of a resistance, such as that of a potentiometer, 300 to 2000 ohms, in the plate circuits of the two amplifier tubes as shown at R and R in Fig. 32.

Wave Trap in an Antenna Circuit.—Sometimes if severe interference is suffered from a single transmitting station nearby which uses a wave length slightly different from the wave length of a station which it is desired to hear, the signals from this interfering station may be made much weaker by connecting a wave-trap or filter in the antenna circuit. The connection of a very simple filter for this purpose is shown in Fig. 33. The

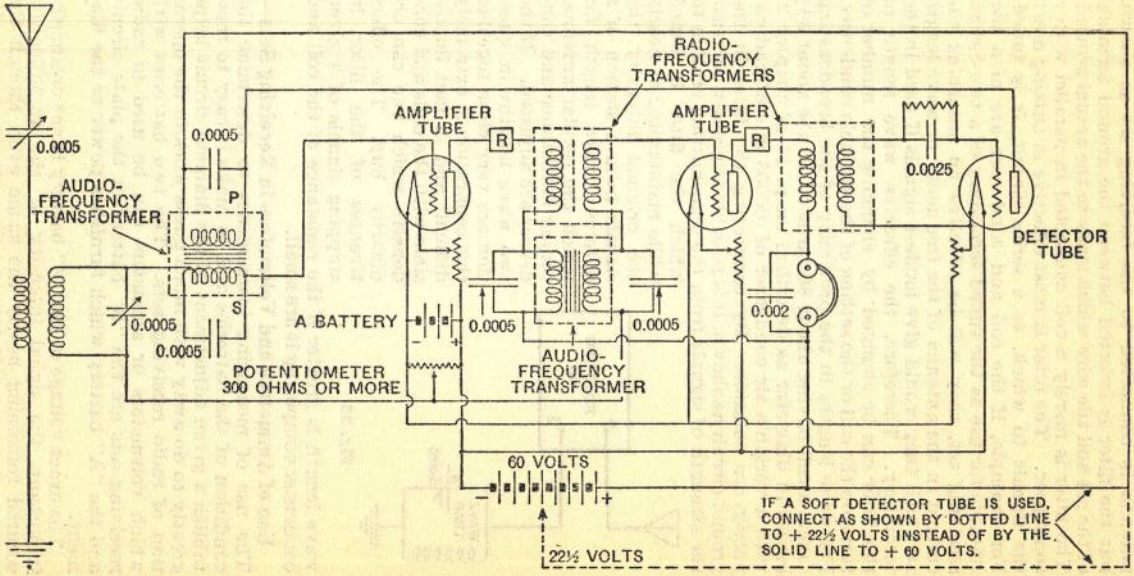


Fig. 32—Three-Tube Reflex Circuit.

antenna is connected to the receiving set as shown, but the filter is inserted between the ground terminal of the set and the wire which leads to the actual ground. The filter is merely a coil connected in parallel with a condenser. The filter is most effective in cutting down the signals to which, as a series circuit, it is tuned. For example, if the coil and condenser are of a size suitable for use as the tuned secondary of a two-circuit receiving set, they will be effective on absorbing the current in the antenna of the frequency or wave length at which they would give loudest signals if used in the secondary. Therefore, the effective wave length of this filter can be changed by changing the number of turns on the coil or the setting of the variable condenser. For wave lengths in the proximity of the broadcasting range, a coil having about 80 turns on a tube about 3½ inches in diameter as described on p. 14 of chapter 2, with a variable air condenser of .00005 microfarad capacity are suitable. By connecting the filter in the ground circuit as shown, it is possible to greatly decrease the strength of signals from the transmitting station to which the filter is tuned while maintaining at nearly the original intensity the signals from a station of a different wave length for which the regular antenna, tuning inductance and condenser are adjusted. If the two wave lengths in question are very close together this separation is extremely difficult and in fact impossible with the coils and condensers which one can ordinarily buy. The effectiveness of the filter in stopping signals of a given wave length is greater if the resistance of the coil and condenser composing it are small.

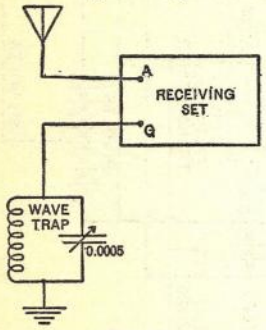


Fig. 33

Use of Ammeters and Voltmeters in Receiving Sets—The use of measuring instruments to determine the condition of the batteries and to make it easy to reestablish a given adjustment of the filament circuit helps greatly to do away with much guess work in the operation of radio receiving sets. The two batteries with which voltmeters or ammeters can be used in radio receiving sets are the "B" battery in the plate circuit and the "A" battery which furnishes power to the filament.

The exact voltage of the "B" battery is not ordinarily important, the signal intensity or the amplification secured remaining nearly the same even though the battery decreases slightly in its voltage during the

course of its use. However, when the battery is nearly discharged the voltage drops rather rapidly and the signals then decrease noticeably in intensity. To determine whether the difficulty in the reception of signals is caused by a worn out or discharged "B" battery, it is convenient to have a voltmeter with which the voltage of the "B" battery can be measured. Since the voltages used in ordinary receiving sets are of the order of 20 volts for the detector tube and 40 to 80 volts for the amplifier tube, a direct current voltmeter having a maximum reading of about 100 volts is useful.

In the filament circuit either a voltmeter or an ammeter may be used. An ammeter connected in series with the filament of a tube reads the current flowing through it and through the filament from the "A" battery. When the filament rheostat has been adjusted so that the signals are received most satisfactorily, the reading of the ammeter is noted. Then, at a subsequent time when the receiving set is being used, the filament rheostat can be brought to the position corresponding to this same ammeter reading and the operator can be quite certain that this adjustment is correct and thus give attention to the careful manipulation of tuning, coupling, and regenerative controls. It will be found, however, that as the tube is used the condition of the filament changes, so that the current flowing through it when the best signals are received will become less and less. It is therefore necessary to make a redetermination of the best value of this current. This should be done perhaps once a week.

If a voltmeter is used to read the voltage across the terminals of the electron tube filament, it will be found that this voltage reading for best signals does not change noticeably as the tube ages. A voltmeter is therefore somewhat preferable to an ammeter as an aid in reproducing the proper conditions in the filament circuit. The voltmeter should be connected across the terminals of the filament itself rather than across the battery to which the filament is connected. That is, the voltmeter readings should not include the voltage across the filament and the filament rheostat, but should read the filament voltage alone. The maximum scale reading of the voltmeter should, however, be slightly greater than the normal voltage of the "A" battery when it is fully charged. This voltmeter will, then, be useful in determining whether this battery is becoming discharged as will appear from a definite decrease in the voltage across its terminals.

In using direct current voltmeters care should be taken to connect the plus terminal of the meter to the positive (plus) terminal of the battery. In many batteries the positive terminal is marked with red. In order to avoid the necessity of having separate voltmeters for each of the tubes used in a receiving set, one

may provide jack and plug connections with which the voltmeter can be plugged into each of the filament circuits in turn. The jack used for a voltmeter connection must be an open circuit jack. That is the circuit must not be closed when the plug is removed. The jack used for making connection to an ammeter should, on the contrary, be a closed circuit jack. That is, the circuit should close when the plug is removed, the insertion of the plug making a connection of the ammeter in series in the circuit.

Converting a Crystal Set Into a Long Distance Set.—The distance range of a crystal detector receiving set can of course be increased by connecting an amplifier between the crystal and the phones. A simpler, cheaper and better way, however, is to convert the set into a regenerative set, using a dry-cell electron tube. With the WD-11 tube an ordinary No. 6 dry cell, the kind used for doorbells, is used instead of a storage battery. By adding such a tube to a crystal set and changing to a regenerative connection, stations at distances up to one or two hundred miles can be heard, under good conditions. Exceptional transmission conditions make it possible to receive over distances up to about 1000 miles.

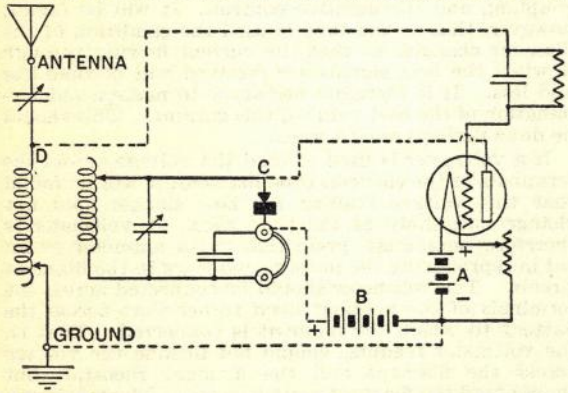


Fig. 34—Regenerative Connection of Electron Tube to a Two-Circuit Crystal Set.

No changes are necessary in the internal connections of the set when you start with a two-circuit crystal set. The ordinary connections of a two-circuit crystal set are shown at the left of Fig. 34. An electron tube with the associated batteries, etc., is shown at the right. The dotted lines between the two show how the connections are made to make the set regenerative. The crystal detector must be out of circuit by having its contact wire raised. If the set does not have a binding-post at points C or D, connection must be made to the proper

switch arm or in some other manner. If the set does not regenerate, the connections to "D" and "Ground" should be reversed.

The parts required for the electron tube detector and their cost, are: WD-11 tube, $6.50; Tube socket, $.75; No. 6 dry cell, $.40; B battery, $2.00; Filament rheostat, $1.50; Grid leak and grid condenser, $1.00.

When you start with a single-circuit crystal set one additional item must be provided, a tickler coil. This

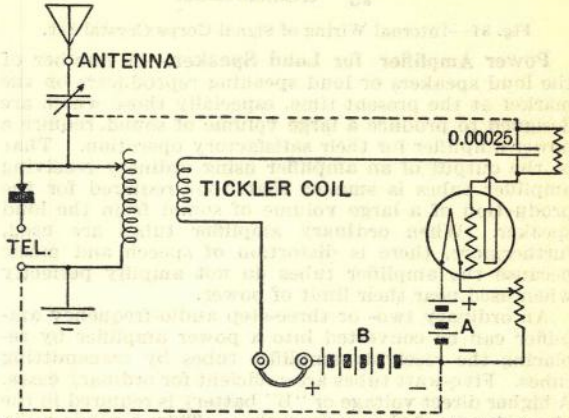


Fig. 35—Regenerative Connection of Electron Tube to a Single Circuit Crystal Set.

may be a simple cardboard tube about 2 inches long and 3 inches in diameter, with about 30 turns of No. 24 to 30 wire wound on it. This must be provided with a means of sliding either inside or over the inductance coil of the set, or else made to rotate within or near it. The ordinary connections of a single-circuit crystal set are shown

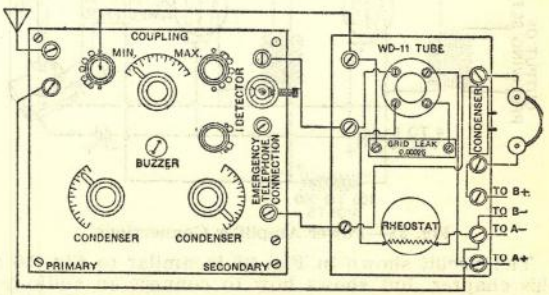


Fig. 36—Connection of Electron Tube Detector to Signal Corps Crystal Set.

at the left of Fig. 35. The dotted lines show how to make the connections to the electron tube and tickler coil.

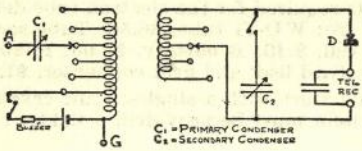


Fig. 37—Internal Wiring of Signal Corps Crystal Set.

Power Amplifier for Loud Speaker.—A number of the loud speakers or loud speaking reproducers on the market at the present time, especially those which are designed to produce a large volume of sound, require a power amplifier for their satisfactory operation. That is, the output of an amplifier using ordinary receiving amplifier tubes is smaller than that required for the production of a large volume of sound from the loud speaker. When ordinary amplifier tubes are used, furthermore, there is distortion of speech and music because the amplifier tubes do not amplify perfectly when used near their limit of power.

An ordinary two- or three-step audio-frequency amplifier can be converted into a power amplifier by replacing the receiving amplifier tubes by transmitting tubes. Five-watt tubes are sufficient for ordinary cases. A higher direct voltage or "B" battery is required in the plate circuit of the power tubes. This depends upon the type of tube used and may be from 100 to 300 volts. If only moderate power is required, the last stage of the amplifier need be the only one having a power tube. It, then, would be the only one for which a higher plate voltage is required.

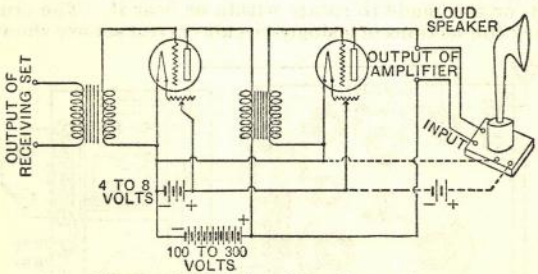


Fig. 38—Power Amplifier Connections.

The circuit shown in Fig. 38 is similar to Fig. 16 of this chapter, but shows how to connect an audio-frequency amplifier to a receiving set which is already in use having a single electron tube detector. The input

terminals of the amplifier are connected to the telephone receiver terminals of the receiving set, the telephone receivers being entirely removed. The output terminals of the amplifier are connected to the input terminals of the loud-speaker. The same filament (or "A") battery may be used for both receiving set and amplifier, though care must be taken to have a large enough battery to supply adequately the current required by the filaments of the power tubes.

Some types of loud speakers require a connection to a source of power in addition to the connections from amplifier circuit to the input terminals. The filament battery used with the tubes may be used also to supply this power to the loud speaker if the voltage is of the correct value. If, however, the loud speaker requires a slightly higher voltage than the electron tube filaments, an additional battery can be connected in series with the connection from the loud speaker to the filament battery as shown by the dotted lines.

The "B" or plate voltage for the power amplifier tubes may be secured from either storage cells or dry cells. On account of the larger currents required for the plate circuits of transmitting tubes the "B" batteries used should be capable of supplying larger currents than are required in "B" batteries for receiving sets having only one or two tubes. Otherwise the batteries will deteriorate rapidly and decrease in voltage.

If the impedance of the loud speaker to an alternating current of voice frequency (say 500 to 2000 cycles) is not approximately the same as the out put (or impedance) of the electron tube, a transformer is needed for connecting the two together. The input impedance of this transformer should be equal to the output impedance of the tube and the output impedance of the transformer should be equal to the input impedance of the loud speaker.

Two amplifier tubes can be connected in parallel, as shown below, when it is desired to get increased volume without overworking the tubes.

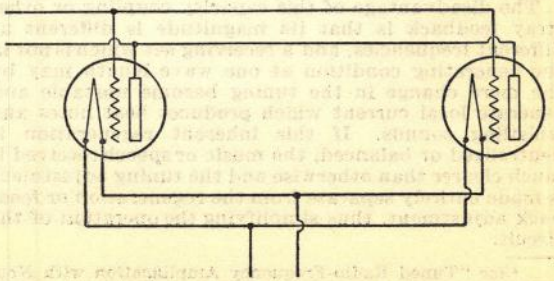


Fig. 39—Two Amplifying Tubes in Parallel.

Neutrodyne Receiving Circuit.—Radio-frequency amplifiers are designed to transform the voltage of the incoming wave into currents of higher voltages in each successive step of amplification. Ideally each stage of a radio-frequency amplifier is a one-way relay which passes the incoming power only in the one desired direction. However, on account of the proximity of the plate, grid, and filament of an electron tube to one another, there is always present a certain amount of coupling between the output and the input circuits of the amplifier. This coupling in effect causes a slight amount of regeneration or feedback through the capacity between the tube elements unless devices are used to neutralize it. One way of neutralizing or balancing the capacity coupling through an electron tube is that described by L. A. Hazeltine before the Radio Club of America on March 2, 1923.*

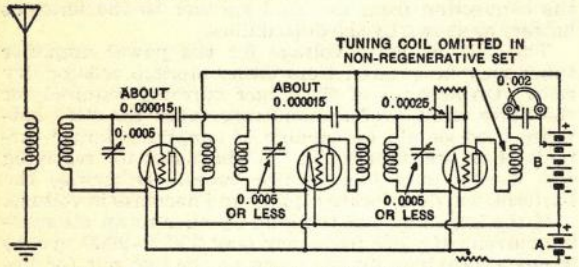


Fig. 40—Diagram of Regenerative Neutrodyne.

In almost all radio-frequency amplifier circuits there is present some inherent regeneration even though the circuits be designed as non-regenerative circuits. The tube capacities referred to above are perhaps the principal cause, though the fact that various parts of the circuit are placed near to one another in a receiving set results in capacity between input and output circuits in addition to this tube capacity.

The disadvantage of this capacity coupling or other stray feedback is that its magnitude is different at different frequencies, and a receiving set which is not in the generating condition at one wave length may by the mere change in the tuning become unstable and generate local current which produces beat notes and whistling sounds. If this inherent regeneration is neutralized or balanced, the music or speech received is much clearer than otherwise and the tuning adjustment is made entirely separate from the regeneration or feedback adjustment, thus simplifying the operation of the circuit.

*See "Tuned Radio-Frequency Amplification with Neutralization of Capacity Coupling," by L. A. Hazeltine, QST 6, p. 7, April, 1923.

To reduce or balance this capacity feedback through the tube, Professor Hazeltine connects a small condenser from the grid of one tube to one terminal of the secondary winding of the next tuned radio-frequency transformer. The circuit used in a regenerative neutrodyne receiver is shown in Fig. 40. Fig. 41 shows a non-regenerative neutrodyne receiver with one stage of audio-frequency amplification. Fig. 42 shows a neutrodyne receiver in which a reflex connection is employed to utilize two of the tubes both as radio-frequency and as audio-frequency amplifiers. Each stage of a neutrodyne receiver should be thoroughly shielded from the

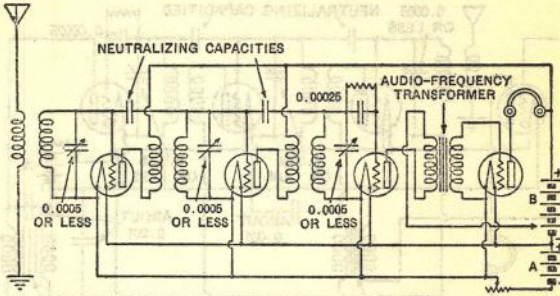


Fig. 41—Diagram of Non-Regenerative Neutrodyne.

next adjacent stages by means of partitions and metal linings in the amplifier cabinet. The terminal of the transformer secondary winding to which the neutralizing condenser is connected is dependent upon the direction of the windings. This can be determined by trial, the connections to the secondary terminals being interchanged or the direction of the winding reversed if necessary.

The proper capacity or size for this neutralizing condenser is dependent upon the capacity between the grid and plate of the amplifier tube and also upon the ratio of the number of turns in the amplifier transformer windings. Hazeltine gives the relation between these quantities as $\frac{N_1}{N_2} = \frac{C_2}{C_1}$

where N_1/N_2 is the ratio of turns on the primary and secondary windings.

C_1 is the capacity between the grid and plate of the tube and C_2 is the capacity of the neutralizing condenser. A ratio of transformation of 1 to 1 is found in many radio-frequency transformers. In this case the neutralizing condenser has the same capacity as that between the tube elements, which is usually about 10 or 15 micro-microfarads. It may be seen, therefore, that this capacity can be secured by using two very

small metal plates or two very small and short cylinders which slide within one another though insulated from each other.

The adjustment of each neutralizing capacity is made experimentally by tuning in a very strong signal and then disconnecting the filament of the tube whose capacity is to be adjusted, but leaving the tube in its socket. If the neutralizing capacity is not correct, the circuits on each side of the tube will have capacity coupling which will transmit the signal. The neutralizing capacity is then adjusted until the signal disappears.

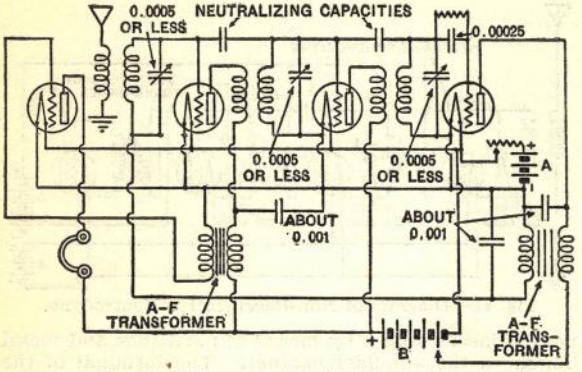


Fig. 42—Diagram of Reflex Neutrodyne.

This neutrodyne circuit is most effective when care is taken to have sharply tuned radio-frequency transformers, though the adjustments required are more complicated if sharper tuning and greater selectivity are attained.

There is no reradiation from the antenna of a neutrodyne receiver even when a regenerative circuit is used with the detector tube. Amplifier tubes may be used throughout, the choice of A and B batteries being determined by the type of tube employed as in any ordinary receiving set.

Flewelling Circuit.—A circuit which is interesting for the radio experimenter is that shown in Fig. 43 and which has been called the Flewelling circuit. It is essentially a regenerative receiving circuit to which some auxiliaries are added. Its behavior is very much like the Armstrong super-regenerative circuit and in fact it probably makes use of super regeneration in its operation. The principal tuned circuit is identical with that of a single circuit regenerative receiving set. There is also a feedback or tickler coil connected in the plate circuit and coupled with the inductance of the tuned circuit to give regeneration. The antenna and ground

connections are brought to the two terminals of the tuning condenser C_1. The additional apparatus required consists of three fixed condensers of 0.006 microfarad capacity each, and a high resistance which may be a grid leak of 0.5 megohm. In addition it is necessary that the grid leak resistance used with the customary grid condenser be a variable one.

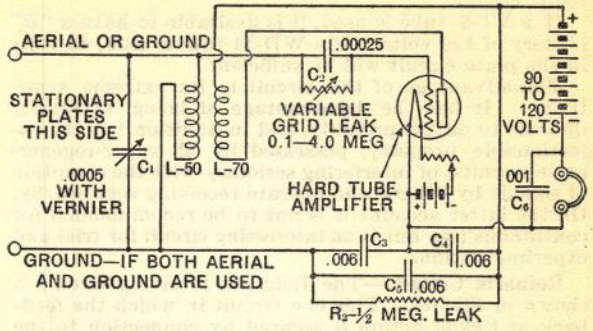


Fig. 43—Diagram of Flewelling Circuit.

When the circuit is first set up, the condensers C_3, C_4, and C_5 can be omitted, a short-circuiting wire being connected in place of the condenser C_3. Without these condensers the circuit is simply an ordinary regenerative circuit, and signals should be received as with such a circuit before connecting in the additional condensers. After connecting these condensers the operator should hear a steady singing or high-pitched whistle in the telephones. The amount of amplification secured depends upon the pitch of this whistling sound. This pitch is controlled by changing the resistance of the grid leak R_1. For this purpose it is convenient to have a variable grid leak having a resistance of from 0.1 to 4.0 megohms. It is possible to purchase variable grid leak resistors or one can use a piece of paper or fiber on which a mark is made with a soft pencil or with India ink. When the proper adjustment is obtained, the whistle should have a high pitch which is just barely audible. While somewhat greater amplification is obtained with a lower pitch, the whistle is correspondingly more noticeable and interferes with satisfactory reception. If the tone is too low or prominent, the resistance of the grid leak should be increased. If the pitch is too high, the resistance should be decreased. If the grid leak is made by a pencil or ink mark it is likely to change with changing atmospheric conditions, though it can be protected by clamping between pieces of glass or mica.

The sizes of the condensers C_3, C_4 and C_5 are not critical, the most critical part of the circuit being the

grid condenser C_2 and its grid leak resistance. When properly adjusted this circuit is extremely sensitive, and it has been reported that signals are sometimes received with the ground connection only, without any ordinary antenna. If the circuit sings or whistles when tried alone and becomes silent when the antenna is connected to it, a series condenser should be connected in the antenna circuit.

If a VT-2 tube is used, it is desirable to have a "B" battery of 120 volts. If a WD-11 tube is used, 45 volts in the plate circuit will be sufficient.

The advantage of this circuit is its extreme sensitivity. It has the disadvantage of being extremely difficult to adjust properly, and in addition has the objectionable property, possessed by all super-regenerative circuits, of interfering seriously with the reception of signals by others who operate receiving sets nearby. On the latter account it is not to be recommended for continuous use, but is an interesting circuit for trial and experimentation.

Reinartz Circuit.—The Reinartz receiving circuit is shown in Fig. 44. This is a circuit in which the feedback or tickler action is secured by connection to the coil which also forms part of the tuned circuit. A condenser is also connected between the plate of a detector tube and the antenna. The antenna circuit itself is not tuned. The antenna may therefore be much longer

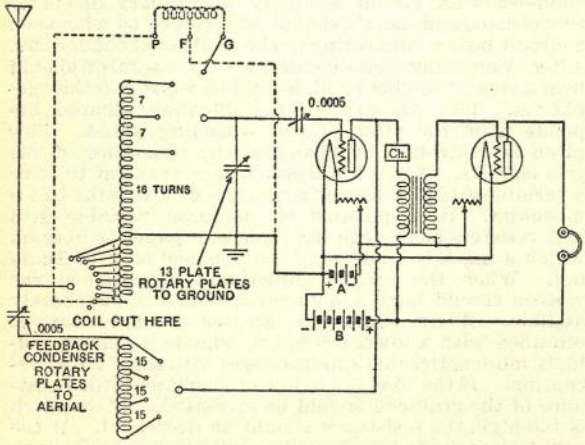


Fig. 44—Diagram of Reinartz Circuit.

than is ordinarily possible when it must be tuned to the received signals. The tuning of the secondary circuit is relied upon to secure selectivity. The circuit is shown in diagrammatic form in Fig. 45. In actual use

it is convenient to have a pair of taps brought out from the tuning inductance to three separate switches, as shown in Fig. 44. The coil can be wound continuously on a single form and cut into two parts at a point near the middle, as shown in the figure. The so-called "spider web winding" has been found by many experimenters to be convenient, since the wires to the switch contacts can be brought out in a compact way. If this form of winding is used, eighty-five turns of No. 26 single cotton-covered wire should be wound on a nine-spoke wheel, thus forming a coil 5 inches in outside diameter and having an open center 2½ inches in diameter. A coil thus constructed will enable the receiving set to cover a range from 130 to 360 meters. If it is desired to receive longer wave signals, a proportionately larger number of turns may be used all along the coil, or a loading coil may be inserted, as shown at P, F, and G of Fig. 44. This figure also shows the connections to a single amplifier tube through an audio-frequency transformer. The insertion of a radio-frequency choke coil at the point marked Ch. in the plate circuit of the detector tube will serve to increase the strength of the signals in case the distributed capacity of the primary winding of the amplifier transformer is large.

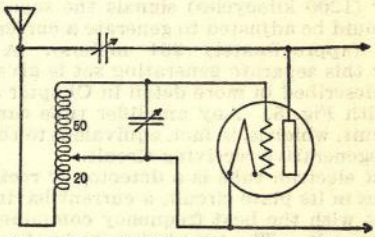


Fig. 45—Schematic Diagram of Reinartz Circuit.

In actual use this circuit is quite similar to the ordinary single circuit regenerative receiving set, regeneration being here controlled by means of a condenser connected to the antenna. The setting of this condenser does not change very much with wave length. The use of this method of feedback also tends to minimize the effect of the capacity between the circuit and the hand of the operator. In sensitivity the circuit is probably about the same as the ordinary regenerative circuit using tickler feedback. It has the disadvantage of causing reradiation and thus interfering to some extent with the reception of signals at other receiving stations nearby.

ARMSTRONG SUPER-HETERODYNE CIRCUIT

This circuit was originally described by E. H. Armstrong in an article entitled "A New Circuit of Short Wave Amplification," published in the Proceedings of the Institute of Radio Engineers for February, 1921. Additional notes on its operation were given by C. R. Leutz in an article entitled "Notes on a Super-Heterodyne," published in the magazine QST for December, 1922. The circuit diagram is given in Fig. 46. The antenna and secondary tuned circuit are identical with those ordinarily used in radio reception. The super-heterodyne circuit is useful chiefly for receiving short wave radio signals. Fundamentally, it transforms the received signals of extremely high frequency to a lower frequency which can be more easily amplified. The lower frequency currents after amplification are rectified by a detector tube and made audible in the telephone receivers.

The transformation of the high frequency currents to a lower frequency is accomplished by means of a heterodyne, which for most satisfactory use should be kept separate from the receiving set proper. This separate heterodyne is actually only a continuous wave generating set of low power which will generate current of a frequency nearly the same as that of the incoming signal. This separate heterodyne is coupled to the secondary circuit of the receiving set. For receiving 250 meter (1200 kilocycles) signals the separate heterodyne should be adjusted to generate a current of 1300 kilocycles (approximately 231 meters). A suitable circuit for this separate generating set is given in Fig. 47 and is described in more detail in Chapter 5, in connection with Fig. 8. Any amplifier tube can be used in this circuit, which is, in fact, equivalent to the secondary of a regenerative receiving circuit.

The first electron tube is a detector or rectifier tube which gives in its plate circuit, a current having a D.C. component with the beat frequency component superimposed upon it. The tuned circuits in the plate circuit of the first tube and the grid circuit of the second tube are adjusted to resonance with the beats (for example, 100 kilocycles or 3000 meters) produced by the received signals and the super-heterodyne. When once adjusted these two circuits can be left alone.

The next three tubes shown in the circuit, Fig. 46, are radio-frequency amplifier tubes with resistance coupling between the several stages. The next to last tube is another detector tube. The last tube is an audio-frequency amplifier. By using hard or high-vacuum tubes both as amplifiers and detectors, the connection to the batteries is simpler and the adjustments required are less complicated.

As a whole, the circuit is rather difficult to adjust when it is first being set up, but after this its use is

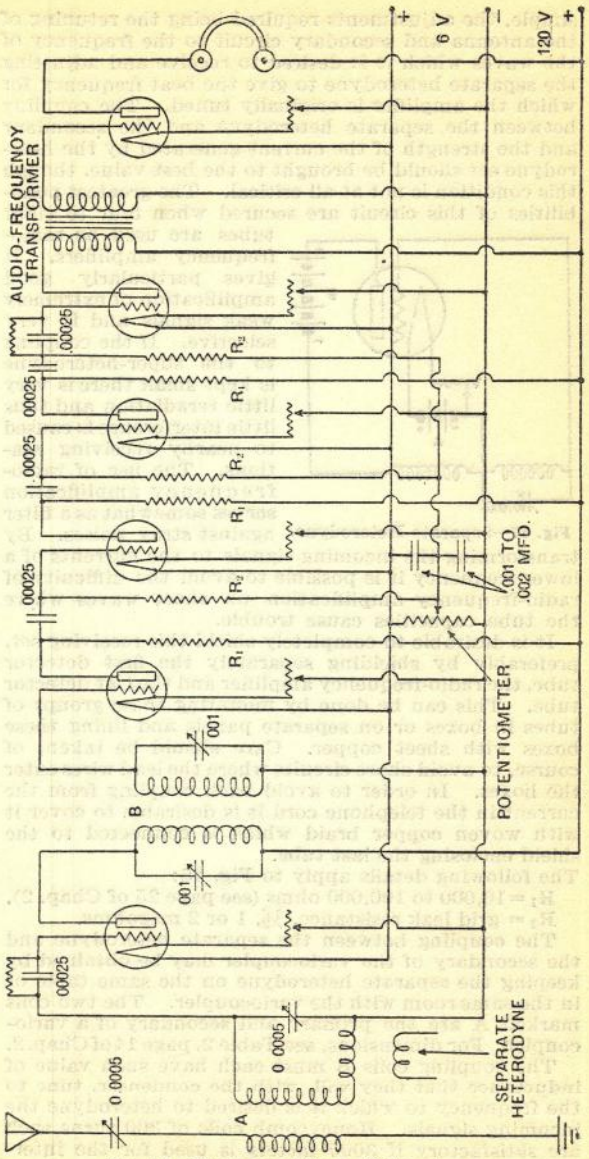


Fig. 46—Diagram of Super-Heterodyne.

simple, the adjustments required being the retuning of the antenna and secondary circuit to the frequency of the waves which it is desired to receive and adjusting the separate heterodyne to give the beat frequency for which the amplifier is originally tuned. The coupling between the separate heterodyne and the secondary and the strength of the current generated by the heterodyne set should be brought to the best value, though this condition is not at all critical. The greatest possibilities of this circuit are secured when four to eight tubes are used as radio-frequency amplifiers. It gives particularly good amplification of extremely weak signals and is very selective. If the coupling to the super-heterodyne is kept small there is very little reradiation and thus little interference is caused to nearby receiving stations. The use of radio-frequency amplification serves somewhat as a filter against stray noises. By transforming the incoming signals to the currents of a lower frequency it is possible to avoid the difficulty of radio-frequency amplification on short waves where the tube capacities cause trouble.

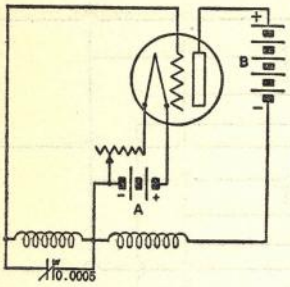


Fig. 47—Separate Heterodyne.

It is desirable to completely shield this receiving set, preferably by shielding separately the first detector tube, the radio-frequency amplifier and the last detector tube. This can be done by mounting these groups of tubes in boxes or on separate panels and lining these boxes with sheet copper. Care should be taken, of course, to avoid short circuits where the lead wires enter the boxes. In order to avoid back coupling from the current in the telephone cord it is desirable to cover it with woven copper braid which is connected to the shield enclosing the last tube.

The following details apply to Fig. 46:

R_1 = 10,000 to 100,000 ohms (see page 25 of Chap. 2).

R_2 = grid leak resistance, ½, 1 or 2 megohms.

The coupling between the separate heterodyne and the secondary of the variocoupler may be obtained by keeping the separate heterodyne on the same table or in the same room with the variocoupler. The two coils marked A are the primary and secondary of a variocoupler. For dimensions, see Table 2, page 14 of Chap. 2.

The coupling coils B must each have such value of inductance that they will, with the condenser, tune to the frequency to which it is desired to heterodyne the incoming signals. Honeycomb coils of 300 turns each are satisfactory if 3000 meters is used for the intermediate wave length.

CHAPTER THREE

ANTENNAS

Size.—In radio communication it is necessary to have a device for radiating radio waves from the transmitting station and for receiving the radio waves from the air at the receiving station. Such devices are called antennas. Many types of antennas are in general use. The particular location in which the antenna is to be constructed usually goes far to determine its dimensions. The two general classes of antennas are, first, the ordinary elevated wire type usually called simply an "antenna," second, a "coil antenna" (sometimes called a "loop" or "frame aerial") which is usually made by winding a number of turns of wire around a rectangular frame. This latter type is usable indoors. For receiving stations an antenna of the first type is usually the most satisfactory, a good form being a single wire about 75 or 100 feet long and raised 30 to 50 feet above the ground. The higher it is above the ground, the better. The natural wave length of such an antenna is about 200 meters, but the wave length to which the antenna circuit tunes is increased by inserting the inductance coil. The addition of more wires to such a single wire antenna is of but little advantage in securing louder signals. In case the antenna is necessarily shorter than about 75 feet it is desirable to construct it of two wires placed parallel to one another and about 3 feet apart. The wires should be connected together at the distant end and also at the near end. From this latter, near-by, end the "lead-in" wire is brought to the point marked "antenna" on the receiving set.

If necessary, the connection of the lead-in wire may be made to the center of the antenna wires instead of to the end. But this shortens the effective length of the antenna and makes it necessary to add to the series inductance in order to tune to a given wave length, thus somewhat decreasing the strength of the signals.

Figs. 1 to 7 inc. show a number of suggested methods of installing simple antennas. The antenna wires may be strung inside the attic of a house, but care should be taken to locate them as free as possible from proximity to surrounding objects. It is especially desirable to keep the antenna wires some distance from wires used for electric light and power purposes. Antennas

should not be run either under or over electric power lines.

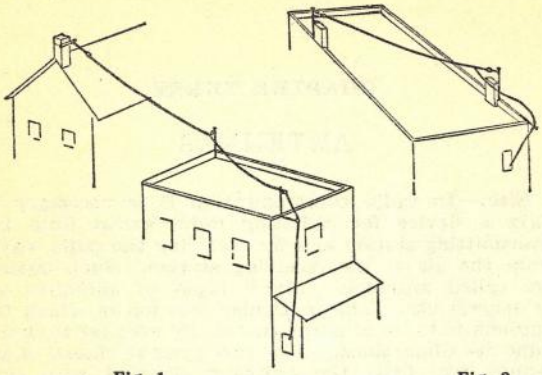


Fig. 1 Fig. 2

Fig. 1—A single continuous wire antenna. Where wire passes over edge of roof it is prevented from coming in contact with the building by the insulators at the end of the wood poles.

Fig. 2—A single wire antenna with lead-in held away from edge of building by insulator on end of pole.

For receiving purposes alone it is sometimes satisfactory to use a wire laid near or along the ground though in this case as in the case of the coil antenna, which is described in more detail below, it is necessary to have very sensitive amplifiers in order to receive loud signals from a distant station.

Material.—The usual material for constructing antennas is 7-strand No. 22 hard drawn copper or

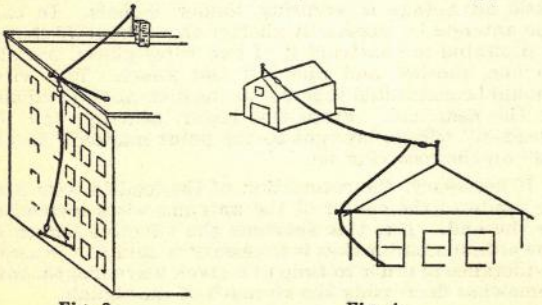


Fig. 3 Fig. 4

Fig. 3—A single wire antenna showing how advantage can be taken of the height of a building to get the necessary length. The horizontal length is very short compared to the vertical. The wire is held away from the building by running it through insulators on the end of poles.

Fig. 4—A single wire antenna with lead-in held away from edge of roof.

phosphor bronze wire, though No. 14 or larger bare hard drawn copper is also quite satisfactory. If the antenna is used mainly for receiving signals from long wave stations it is desirable to make it considerably longer than the 75 feet previously mentioned.

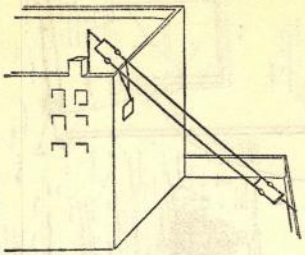


Fig. 5

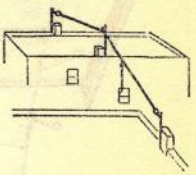


Fig. 6

Fig. 5—A two-wire antenna. The pole on the roof must be sufficiently high or so located that the antenna is held well away from the edge of the roof. This type is not as efficient as one where the entire antenna is above the building.

Fig. 6—A single wire antenna with lead-in taken from the center.

Insulation.—Each end of the antenna should be insulated from its support by means of an insulator. Almost any insulator of glazed porcelain, glass, impregnated wood, or other material which will not absorb moisture and which has a length of several inches will be satisfactory for receiving antennas. Sometimes two or three porcelain cleats are used in series, the farther one being connected to a rope or heavy cord which is run through a pulley for convenience in raising or lowering the antenna. The lead-in wire should be held away from the building and should enter the room where the receiving apparatus is located through a lead-in bushing or insulator. A small hole may be made in a window pane or the wire may be mounted in any way which will insure its not becoming grounded during wet weather. Inside of the house the wiring should be as short and direct as possible and should not run close to the other wires or water pipes except where the ground connection is made. The receiving apparatus should be located as close as convenient to the entrance of the wire into the room.

Ground Connection.—A good ground connection is usually secured by connection to a water pipe or any thoroughly grounded metal structure. Sometimes louder signals may be secured by using several different ground connections together. If, however, one of the ground connections is poor and has a long connecting wire it may reduce the audibility of signals below that obtained with a single connection. It is usually

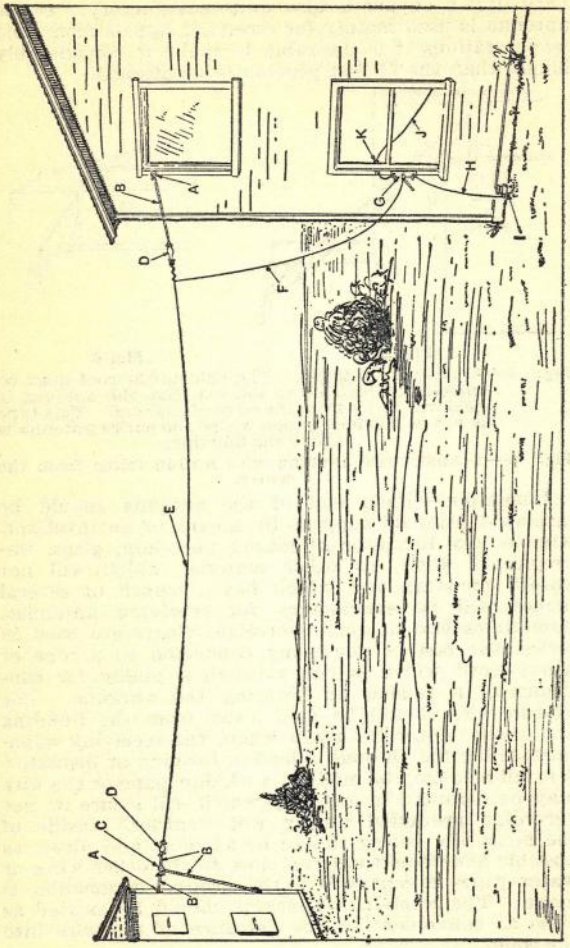


Fig. 7

Fig. 7—Complete detail of single-wire antenna and lead-in: A—screw eye, B—rope, C—pulley, D—insulator, E—antenna, F—lead-in wire, G—lightning switch, H—ground wire, I—ground pipe, J—lead to receiving set, K—insulating tube used where lead-in passes through window frame.

not as satisfactory to use a rod or pipe driven into the ground since the soil surrounding the pipe may become dry and fail to make good connection. To insure good electrical contact with the grounding system, both the pipe and wire connecting to it should be well scraped and the connection made with an approved connecting clamp or else thoroughly soldered. It should be as short as possible.

Protection against Lightning.—The Fire Underwriters' rules require the installation of an approved device for protection against lightning. This should be connected between the antenna lead-in wire and the ground wire at some point very close to the entrance of the antenna to the building. The protective device may be mounted on the receiving set itself if this is located close to the point where the antenna lead-in wire enters the building. While it is not required, it is desirable in receiving sets to employ in addition a single pole double throw knife switch to disconnect the antenna from the receiving set and connect the antenna directly to the ground. This does not obviate the requirement for the protective device which must then be connected so that it will be short circuited by the antenna switch as shown in Fig. 10. It is important that the wires used for the antenna lead-in and for the ground connection be large enough to withstand any danger of mechanical breakage to which they may be subject, while the lead-in wire should be kept from coming in contact with any conducting objects up to the point where it is connected to the receiving set. It is not necessary to insulate the ground wire unless it is an extremely long one. Protective devices, grounding clamps and antenna switches may be purchased from any dealer in radio receiving sets or parts.

Transmitting Antennas.—The most common form of antenna at a radio transmitting station consists of several long parallel horizontal wires with a "lead-in" wire attached to the center or to one end of the horizontal portion. They are called "flat top" antennas, of the "T" or the "inverted L" type. The "fan" or "harp" antenna consists of a number of wires extending upward and spreading somewhat from a common point. A good antenna where tall supporting structures are available is the "cage" antenna, which consists of a number of parallel wires held in a vertical position and separated from one another by spreaders or a barrel hoop. This type can also be used horizontally. None of these forms are superior to the single wire for receiving.

The requirements as to the insulation of antennas used at transmitting stations are more severe on account of the high voltages which are created in the antenna by a transmitting set. The antenna and lead-in wire must be supported at least five inches away from the building

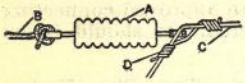


Fig. 8

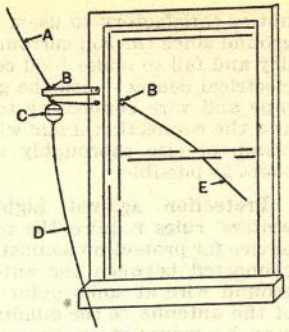


Fig. 9

Fig. 8—Detail at insulator showing how antenna wire may be passed through the eye of the insulator and be secured by a tie wire. A—insulator, B—rope for raising and lowering the antenna, C—antenna wire, D—tie wire. This arrangement allows the use of a continuous wire forming both antenna and lead-in, thus eliminating the necessity for soldered joints.

Fig. 9—Detail showing arrangement of lightning arrester. A—lead-in from antenna, B—insulating tube through board used to hold lead-in away from building and where lead-in passes through window frame, C—lightning arrester, D—ground wire, E—wire to receiving instruments. Care must be taken that no appreciable strain is placed on the binding posts of the lightning arrester.

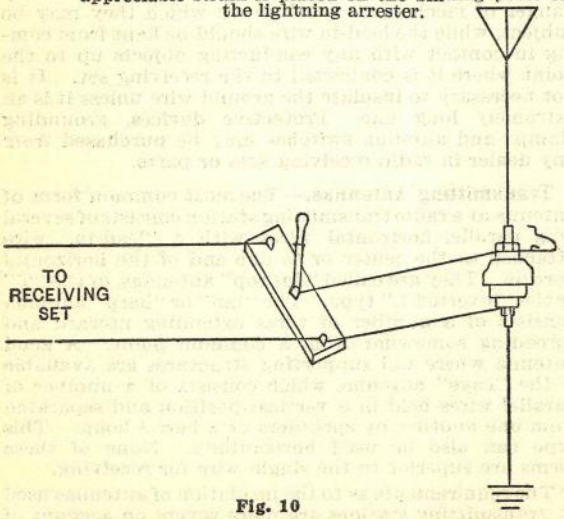


Fig. 10

Fig. 10—Wiring arrangement when using both a lightning switch and a lightning arrester. When lightning switch is thrown to the lower position, thus grounding the antenna, the arrester is short circuited.

wall. The protective device referred to above is not required on transmitting sets, but instead it is necessary to install a grounding switch which will carry a current of 60 amperes and which has a spacing of at least 5 inches between the central contact and either end connection. The wire leading to the ground from this switch need not be insulated but must, as in the case of receiving installations, be thoroughly strong mechanically.

Counterpoise.—Sometimes it is convenient, instead of making a connection through the receiving set to the ground, to replace the ground connection by a wire running to a set of wires which approximately duplicates the antenna. This set of wires is called a counterpoise. This is more commonly used at transmitting stations than at receiving stations. It is often convenient to run the counterpoise wires out in several directions from the radio set, supported a foot or so above the ground and insulated from it. The wires should cover an area at least as large as that covered by the antenna and should be placed below the antenna. Under some conditions of the surroundings of a radio station it is found to be an advantage to connect the transmitting set to both the ground and a counterpoise. When a counterpoise is used, both the antenna and counterpoise wires must be connected to the ground through the approved protective device as a protection against lightning. A counterpoise is especially useful where the ground is very dry or where the receiving set is located in one of the upper floors of a tall building where the distance to the ground is especially great.

Directional Properties.—A long low antenna is somewhat directional in its action, that is, it will receive signals slightly better when the long open end (the end opposite the lead-in connection) is pointed in a direction away from the transmitting station which it is desired to hear. For short antennas, however, this effect is not very noticeable and it makes little difference in which direction the antenna is strung. For further information regarding the directional and other properties of antennas, as well as suggestions for the construction of antennas and counterpoises of different types, the reader is referred to the book "The Principles Underlying Radio Communication.*"

Coil Antennas.—A compact and sometimes very satisfactory type of antenna is the coil antenna which consists of a few turns of wire wound on a wooden frame about four feet square. No ground connection is required on an antenna of this type. Arrangements of such an antenna are shown in Figs. 11, 12 and 13.

*The "Principles Underlying Radio Communication" is published as Signal Corps Radio Communication Pamphlet No 40, prepared by the U. S. Bureau of Standards. It may be purchased from the Supt. of Documents, Government Printing Office, Washington, D. C., for $1.00.

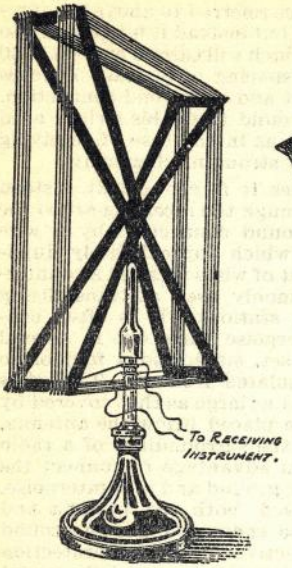


Fig. 11

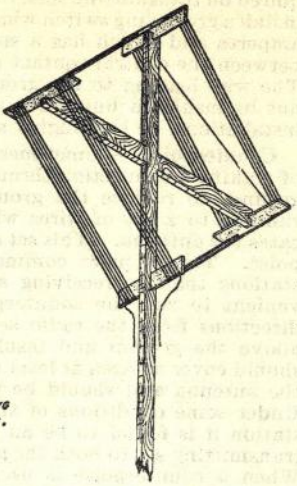


Fig. 12

Fig. 11—Coil antenna mounted on pedestal and arranged to allow revolving coil around its vertical axis.

Fig. 12—Coil antenna on wood frame fitted with end pieces of sheet insulation such as bakelite or hard rubber. To be mounted so that coil can be revolved. The two ends of the coil shown hanging at side of support are to be connected to the receiving instruments.

On account of the small size of this antenna it cannot be used satisfactory for receiving very distant stations unless sensitive amplifiers are employed with it. However, for nearby stations or where good amplification is available the coil antenna has many advantages. One of the most important of these is its directional characteristic. When the coil is turned so that its plane is in the line of direction toward the transmitting station the loudest signals are received. When the coil is turned at right angles to this direction either no signals or only weak signals are received. This makes it possible to receive messages from some stations while avoiding the reception of messages from others even though the stations are transmitting on the same wave length.

Circuits for Coil Antenna.—For receiving from nearby stations on a coil antenna it is desirable to have an electron tube detector and two stages of audio frequency amplification. For receiving from stations 50 or 100 miles away it is advisable to employ five or six stages of

amplification. The above statements refer chiefly to the reception from transmitting stations, such as are ordinarily used for radio telephone broadcasting.

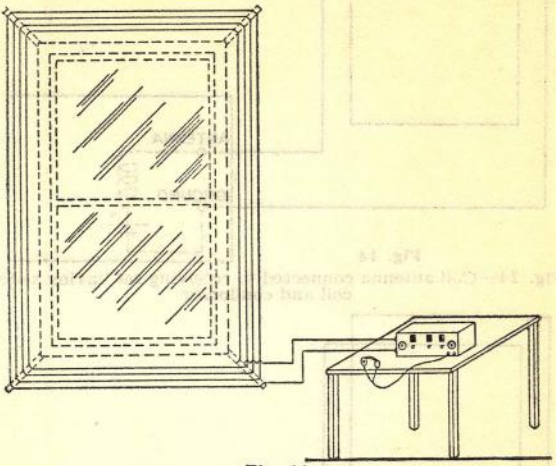


Fig. 13

Fig. 13—A coil antenna made by wrapping a length of wire around a window. The wire is held in place by being forced into saw kerfs in pieces of sheet insulation placed at each corner as shown. This type is of course fixed in position and full advantage of the directional quality of coils can not be obtained.

However, if coils are wound with a large number of turns of wire they can be used even with only moderate amplification to receive signals from European stations. A coil antenna may be connected to an ordinary receiving set. The actual connection which is used depends upon the wiring of the inside of the receiving set. If the receiving set or tuner has a series condenser the coil antenna may simply have its two terminal wires connected to the antenna and ground binding posts of the receiving set as shown in Fig. 14. If the receiving set or tuner does not have a series condenser it is necessary to connect a variable condenser in series with one side of the coil antenna, between it and the ground terminal of the tuner. The other terminal of the coil is connected to the antenna binding post of the tuner. This connection is shown in Fig. 15. It is very simple to use the coil antenna and an extra variable air condenser in place of the regular tuner. In this case the condenser is connected across the terminals of the coil and these two terminals are also connected to the grid and filament terminals of the detector or radio-frequency amplifier which is used. This circuit is very simple as may be seen by reference to Fig. 16.

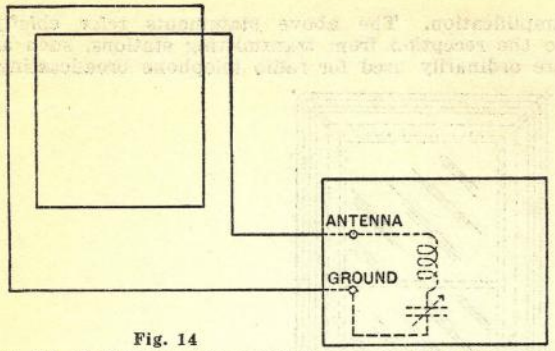


Fig. 14

Fig. 14—Coil antenna connected to receiving set having series coil and condenser

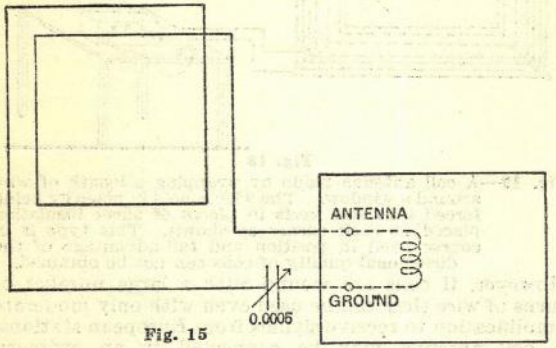


Fig. 15

Fig. 15—Coil antenna and tuning condenser connected to receiving set having series coil only.

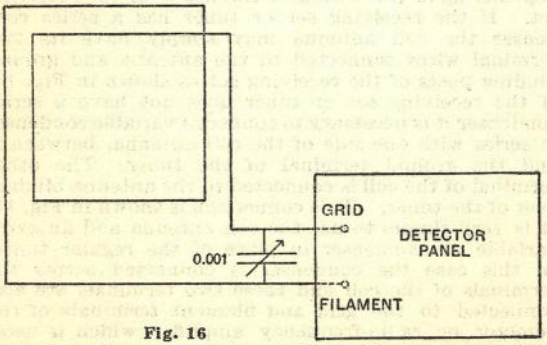


Fig. 16

Fig. 16—Coil antenna and variable condenser connected to detector panel.

Construction of Coil Antennas.—In constructing a coil antenna for receiving, it is desirable to use as many turns of wire as possible without exceeding the wave length of the station to which it is desired to listen. This means that for short waves one can use only a few turns of wire while for long waves a large number of turns may be wound on a frame. Square coils are usually found most convenient to construct. Figs. 14, 15 and 16 show a number of types of coil antennas. For receiving from the ordinary radio telephone broadcasting stations it is convenient to use a coil about four feet square wound with four turns of wire spaced ½ inch apart. The following table gives the wave length range to which the coil antenna receiving set can be tuned, assuming several different numbers of turns of wire wound on a frame 5 feet square.

Using variable condenser having maximum capacity 0.00065 microfarad. Minimum capacity 0.00004 microfarad.

Four turns	200 to 400 meters
Eight turns	350 to 700 meters
Sixteen turns	500 to 1000 meters

Using variable condenser having maximum capacity 0.0014 microfarad. Minimum capacity .000004 microfarad.

Four turns	375 to 650 meters
Eight turns	400 to 950 meters
Sixteen turns	675 to 2300 meters

CHAPTER FOUR

FUNDAMENTAL PRINCIPLES OF RADIO

It is a mistake to suppose that radio must remain a mystery because it operates through invisible electrical actions. It is easily possible to obtain an insight into the underlying processes. They are much less complicated than the mechanism of an automobile. The reader who is interested in the explanation of radio will be well repaid by perusing this chapter, especially because it gives him an introduction to electrical principles in general.

The thing about radio that seems mysterious and complicated is, of course, the lack of connecting wires between the place from which the message is transmitted and where it is received. This mystery begins to disappear when we think of some similar happenings. Sounding a certain note in a room will sometimes cause a string in a piano on the other side of the room to resound. Consider another case. Suppose you are watching a chip floating near the edge of a quiet pond. If someone drops a stone in the middle of the pond, the water ripples spread out in rings and soon the chip is bobbing up and down. This is very much indeed like radio. The stone corresponds to the transmitting station, the chip is the receiving station, and the ripples correspond to the electric waves which constitute radio.

As will be explained later, the radio waves are produced by electric current in the transmitting station, and at the receiving station they are converted into electric current again. So, after all, we really have to deal with electric current, both at the transmitting and the receiving end. Understanding of radio and ability to work with it boils down to understanding of electric current. We, therefore, consider for a while some of the fundamental facts about electric currents and ordinary electricity, and return after that to an explanation of the radio waves in the air between the transmitting and receiving stations.

Electric Current.—When a battery is connected to a metal wire, a something called an electric current flows in the wire. Like anything else, the electric current is useful because of the effect it produces. The two principal effects produced by electric current.

through which it serves mankind, are (1) the heating effect and (2) the magnetic effect. Whenever current flows in a wire it heats it somewhat; this is the basis of electric heating devices and the incandescent lights in our homes. If a very small magnet is brought near a wire in which a current flows the magnet will be deflected; that is, there is a magnetic effect produced near the wire. This is the basis of action of all dynamos and motors, of most electrical machinery, and (as we shall see later) of radio.

In order to have an electric current there must always be a closed "circuit," or path which returns into itself. An electric lamp or any other ordinary electric device is merely a part of this path, and connections must be made so the current can flow up to and away from the device. The path along which the current flows to and away from the electric device must be of conducting material, and is usually a pair

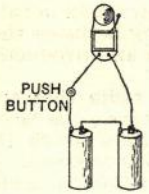


Fig. 1—Simple electric circuit.

of copper wires. For example, when connecting an electric bell, a wire is carried from one terminal of the battery (Fig. 1) to one of the terminals of the bell, and a second wire is brought from the other terminal of the bell back to the remaining terminal of the battery. Any break in the wire immediately causes the current to stop and the bell to be silent. This furnishes an easy method of controlling the ringing of the bell, since it is only necessary to break the wire at one point to stop the current, or to connect across the gap with a piece of metal to start the current going again. Thus we have the button for accomplishing the act of control, and the battery supplies the power required to ring the bell.

Similarly when we are using the city lighting circuit. Wires are brought more or less directly from the power-house to the electric lamp, and a small break in the path through the socket is provided. This can be bridged by a metal spring operated by the key. Sometimes the lamps suddenly go out, and we say that a fuse has been blown. A short length of wire, through which the current has been passing, is of an easily fusible metal which has melted away because too strong a current has been passing. Sometimes the lamps go out because it has become neces-

sary to open a switch at the power-house. It makes absolutely no difference where the break is made in the circuit, the result is the same; the current suddenly stops. Electricity is flowing in every part of the circuit, leaving the battery or dynamo at one side, and coming back to it at the other side.

A useful illustration of the electric circuit is a closed circuit of pipe (Fig. 2) completely filled with water, and provided with a pump, to circulate the water. Electricity behaves in the electric circuit much like an incompressible liquid in a pipe line. We are very sure that electricity is not like any material substance which we know, but the common practice among students and shop men of calling it "juice" shows that they think of it as like a liquid. It is convenient to consider the electric current to be a stream of electricity flowing through the wires. One way of measuring the rapidity with which water is flowing is to let it pass through a meter which registers the total number of quarts or gallons which pass through. By dividing the quantity by the time it has taken to pass we obtain the rapidity of flow. There are instruments by means of which it is possible to measure the total

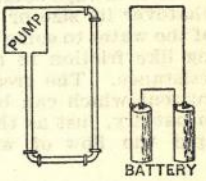


Fig. 2—An electric circuit is like a pipe circuit full of water.

quantity of electricity which passes any point in the circuit during a certain time. If we divide this quantity by the time, we obtain the amount of electricity which has passed in one second; that is, the current. In practical work, however, the current is measured by an instrument called an ammeter, which shows at each moment just how strong the current is, in somewhat the same manner as we may estimate the swiftness of a stream by watching a chip on the surface. This kind of an instrument enables us to tell at a glance what the current is, without the necessity for a long experiment. In this connection it will be remembered that two measuring instruments are to be found on an automobile. The speedometer shows what the speed of the car is at each moment, so that the driver may know instantly whether he is exceeding the speed limit, and govern himself as he sees fit. Another dial shows how many miles have been covered on the trip, and of course the average speed may be

calculated from its indications, if the length of the trip has been timed. The instrument for measuring total quantity of electricity corresponds to the recorder of the total miles traversed; the ammeter corresponds to the speedometer. The ammeter measures the current in a unit called the ampere.

Voltage (Electrical Pressure).—The water will not flow in the pipe line, Fig. 2, unless there is some force pushing it along, such as the pump, and it cannot be kept flowing without keeping up the pressure. Electricity will not flow in a circuit unless there is a battery or other source of electricity in the circuit. The battery is for the purpose of providing an electric pressure. This electric sort of pressure is called voltage. The larger the number of cells which are joined in the circuit the greater the electric pressure and the larger the current produced, just as the rapidity of flow of the water in the pipe line may be increased by increasing the pump pressure. The unit of voltage is the volt, and voltages are measured by an instrument called a voltmeter. The usual city lighting circuits have a voltage of 110 volts, and one cell of a lead storage battery gives two volts.

Resistance.—There is always some friction or resistance in a pipe whatever its size or material, and this hinders the flow of the water to some extent. Similarly there is something like friction in an electric circuit, which is called resistance. The greater the resistance the smaller the current which can be produced in the circuit by a given battery, just as the greater the friction the less rapid the flow of water with a given pump acting.

The unit of resistance is called the "ohm." The current in amperes is equal to the voltage in volts divided by the resistance in ohms.

Friction of any kind causes heat. Electric resistance is similar to frictional resistance, and heat is produced in the conductor which has the resistance. It is not friction of the ordinary kind, but is simply like it in that heat is produced. Just as for the flow of water in a pipe line, the amount of resistance is greater the longer the conductor and is also greater the smaller the cross-section. The resistance, and therefore the amount of heat produced in the conductor by a given current, depend also on the kind of material in the conductor.

Direct and Alternating Current.—When a water pump keeps up a steady pressure the water in the pipe line flows steadily and continuously in the same direction. Just so electric batteries and certain dynamo machines cause a current which flows always in the same direction around the circuit. This kind of current is called direct current. Certain other kinds

of dynamo machines produce current which alternates in direction at some definite frequency; this is called alternating current. The usual frequency of lighting current is 60 per second; that is, the current flows first in one direction and then the other, repeating this 60 times each second. Radio makes use of currents alternating millions of times a second.

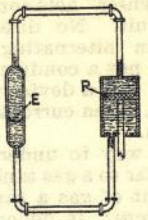


Fig. 3—Alternating water flow, analogous to alternating electric current.

Alternating current is like the sort of water flow that would be produced in a pipe line, if, instead of being acted on by a pump, the water were agitated by a solid piston P as in Fig. 3, which moved back and forth rapidly over a short distance. Under this impetus the water no sooner gets up speed in one direction than it is compelled to slow up and then gather speed in the opposite direction and so on over and over again. The water simply surges, first in one direction, and then in the other so that a small object suspended in the water would not travel continuously around the pipe line, but would simply oscillate back and forth over a short distance.

It is easy to tell whether an electric current is direct or alternating by using it to light a carbon-filament incandescent lamp and holding the lamp near a permanent magnet. If the hot filament is drawn to one side of the bulb and remains there, it is direct current. If the filament vibrates so that it seems to widen out into a bright band, the current is alternating.

Electric devices which depend for their operation on the heat produced by the electric current operate equally well on direct and alternating current. Devices, however, which make use of the magnetic effect of the current may behave very differently with direct and alternating current.

Condenser.—Suppose that an elastic partition E is arranged in the pipe (Fig. 3) so that no water can flow through or around it. If a pump P, or piston, acts steadily, the water moves a short distance until the partition is stretched enough to exert a back pressure on the water equal to the pressure of the pump, and then the movement of the water as a whole ceases. If, on the contrary, a reciprocating motion is given to

the water by P, the water moves back and forth, stretching the partition first in one direction and then in the other, and the water surges back and forth between short limits which are determined by the elasticity of the partition. We have an alternating current of water in spite of the presence of the partition.

An electric "condenser" acts somewhat like an elastic partition in a circuit. No direct current can flow through it, but an alternating current can. The electric condenser is not a conductor, direct current can not flow through it; it is a device which yields a certain amount, so to speak, when current tries to flow through it in either direction.

Perhaps a better way to understand a condenser is to think of it as similar to a gas tank used for the storage of gas. The amount of gas a tank will hold is not a constant fixed amount; it depends on the pressure. If the pressure is doubled, twice the amount of gas is forced into the tank. If the pressure is released and an opening is left in the tank, the gas rushes forth. Similarly, the amount of electricity that can be put into a condenser depends on the electrical pressure, called voltage. When the voltage is increased more electricity flows into the condenser, and when the voltage is diminished the electricity flows out again. By alternately increasing and diminishing the voltage, an alternating electric current flows in the condenser. Thus a condenser allows an alternating current to flow although it contains an insulating partition which prevents the steady flow of direct current.

Electric Energy and Power.—The flow of an electric current is accompanied by the flow of a certain amount of power. The capacity of anything to do work is called energy, and power is the rate at which energy is produced or the number of units of energy produced per second. The purpose of electrical apparatus is the transformation of the power of the current into other forms of power, heat, light and motion. The electric current is the means by which we transmit energy from the power-house to the consumer and we are not, for practical purposes, concerned with the method of carrying the energy any more than we need to inquire into the nature of the belt by which mechanical energy is carried from one wheel to another, or into the chemical nature of the water which is furnishing the power in a hydraulic plant.

The electric current itself cannot be seen, felt, smelt, heard or tasted. Its presence can be detected only by its effects—that is, by what happens when it gives up some of its power, as for example causing a motor to turn. Electrical power is given up, and mechanical power takes its place. Similarly, electric power may be used up and heat or light may appear

in its place. The electric lamp has an effect on the eye. We do not see the electric current in the lamp, but the effect on the eye is due to the light waves sent off by the hot filament. The power of the current has been changed over into heat in the lamp. When we hear a buzzing in the telephone, it is not the electric current we hear, but merely the vibration of the receiver diaphragm. The electric current has used some of the power in moving the diaphragm.

The power which is furnished by the electric current to any electrical apparatus depends both on the amount of the current and the voltage (electric pressure). The power is the product of the two. The product of current in amperes, by voltage in volts gives power in watts. For example, an electric flatiron takes about 5 amperes at 110 volts, so the power which it uses is 550 watts. Another unit of power that is commonly used is the kilowatt, which is simply 1000 watts. Thus, 750 watts is three-quarters of a kilowatt, this is about one horse-power.

The cost of electric service is in proportion to the energy supplied. The energy is the product of the power and the time and it is measured in kilowatt-hours. Thus, if an electric motor uses 2 kilowatts of power, the energy which it uses in 8 hours would be 16 kilowatt-hours. The electric companies that furnish electric current base their charges on the number of kilowatt-hours used. Electric meters give the number of kilowatt-hours used. How to read an electric meter, and how to test the meter, are explained in "Measurements for the Household," Bureau of Standards Circular No. 55, pages 84 to 90. Can be obtained from the Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 45c.

A little study of the following table may assist the reader to understand the units in which electric power and energy, are expressed. The way electric current furnishes power is similar to the flow of water through a pipe system at some point of which a water motor is placed. The power supplied to make this water motor turn and perform work would depend both on the flow of water through it and the pressure acting between the inlet and the outlet of the water motor.

	Water	Electricity
Rate of flow is measured in	Gallons per sec.	amperes
Pressure is measured in...	Lbs per sq. in	volts
Power is measured in....	Horsepower....	watts or kilowatts.
Energy is measured in....	Horsepower-hrs	kilowatt-hours

Sources of Electric Power.—The electric power used in everyday life comes from either of two sources.

These are: (a) dynamos, which operate by means of the magnetic effect of electric current; (b) batteries of chemical cells.

Dynamos will not be discussed here. Suffice it to say that the power furnished by the ordinary house wiring is supplied by dynamos at the electric power house. A complete description and explanation of the dynamos and motors useful in radio is given in "The Principles Underlying Radio Communication," Chapter 2. (See note, page 7, Chap. 3).

The production of electricity by chemical means was discovered in 1786, long before the magnetic effect of the electric current was known. For many years batteries were the only source of electric current, and the cost of producing electric power was very high. In fact it was thought that electric power would never be a commercial possibility, until after Faraday's discovery in 1831 that an electric current is produced by the motion of a wire near a magnet. This discovery made possible the invention of the dynamo. At the present time the amount of electrical energy produced by dynamos is millions of times that produced by batteries.

Batteries.—Although the cost of electrical energy is very great when obtained from batteries, yet it is often advantageous to use them. There are many cases where supply from a dynamo is not available, or batteries are more convenient, as for example, in portable lamps, door bells, and portable radio sets. A battery consists of a number of units called voltaic cells, or simply cells. A cell is a combination of chemicals with two metal terminals. When the terminals are connected by a wire a current flows in the wire, the electrical energy coming from the chemical energy inside the cell.

Among the most commonly used batteries are so-called dry batteries. These are not really dry, but are filled with a material which is moistened with the active solution and then sealed. One terminal is a carbon rod, while sheet zinc forms the containing vessel. This type of cell is made in a variety of shapes and sizes and is now used in large quantities, for use in flashlights, vehicles and all sorts of portable devices as well as radio receiving sets. Attempts are sometimes made to increase the life of dry cells by making a hole in the top and adding water, and also by recharging them electrically like storage cells; but the gain is very slight and seldom worth the trouble.

Storage Batteries.—Dry batteries depend for their operation entirely upon the chemical energy contained in the materials of which they are constructed, and when the cells are exhausted the materials have to be replenished or new cells purchased. In distinction

from such cells are storage cells. These do not contain any available energy, to start out with, but this energy is supplied by passing an electric current through them. This operation is called charging. After being so treated, current can be drawn from them. The process of drawing a current from the battery is called discharging.

The energy which is stored in the cell by the charging process would be stated in watt-hours or kilowatt-hours, like any electrical energy. As already explained, electrical energy in watt-hours is the product of the voltage in volts, the current in amperes, and the time in hours. The last two of these factors taken together, *i. e.*, the current multiplied by the time, gives the quantity of electricity that is put into the cell in the process of charging or converting electrical energy into chemical energy in the cell. The quantity is expressed in ampere-hours. Battery manufacturers have gotten into the habit of rating storage batteries by the number of ampere-hours used in charging.

Only two types of storage cells have proved to be commercially successful. The more common type, called the "lead" storage cell consists of lead plates, the surface of which have been specially treated with lead oxides, immersed in a dilute solution of sulphuric acid. It gives a voltage varying from 2.0 down to 1.75 when discharged. The Edison storage cell has nickel and nickel-iron for the plates, and the solution is an alkali. It gives a voltage varying from 1.4 down to 1.0 volt when discharged.

The filaments of electron tubes, when not operated from the house wiring, are lighted by storage batteries. All electric automobiles are operated by storage batteries. All automobiles having an electric starting equipment, also, have a storage battery to operate the starting motor.

For a more complete discussion of batteries, see "The Principles Underlying Radio Communication," Chapter 1, Section D. (See note, page 7, Chap. 3).

Magnetic Effect of Current.—One of the principal reasons why electricity has revolutionized the everyday life of mankind is that it may be utilized to produce motion. This simple principle makes possible the operation of telegraph and telephone, electric bells, electric motors, elevators and street-cars. The electric motor is also the backbone of many labor-saving devices used in the home, such as the vacuum cleaner, washing machine, electric fan, pump and sewing machine.

The reason that an electric current can cause motion is that every electric current is surrounded by a magnetic field. This is simply shown by the fact that any iron which is near an electric current becomes magnetized and tends to move. The motion of the iron may

be back and forth, as in the telegraph, telephone, or electric bell, or it may be round and round as in a motor.

In an electric bell, the electric current produces a magnetic action which causes motion of an iron piece, then the current is interrupted and the iron piece allowed to fall back to its former position, and then the whole process is repeated over and over. The way in which this is accomplished in the electric bell may be seen from Fig. 4. The contact C is interrupted when the iron piece I is attracted, because of current flowing in the wire. The interruption of the contact stops the current from flowing, the iron piece springs back and makes the contact again, and so the process repeats itself.

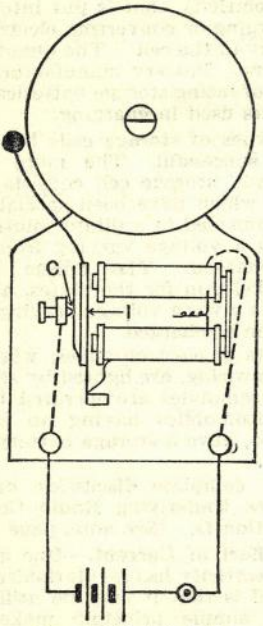


Fig. 4—Electric bell.

Besides causing iron to move, the magnetic field which every electric current produces is responsible for many other important effects. Whenever a magnetic field changes, it tends to produce an electric current in any conductor nearby. Thus a changing electric current causes a changing magnetic field and this in turn causes another electric current in a different conductor. The changing magnetic fields produced by varying electric currents are what make radio possible.

Production of Radio Waves.—Wherever there is an electric circuit in which alternating current is flowing, a magnetic field around the wire is constantly being produced and varied as the current in the wire varies. This magnetic field spreads farther and farther out, giving rise to an electric wave, just as a sound wave starts out from a vibrating bell or tuning fork. A powerful sound can be produced by using a very large tuning fork, and similarly a powerful electric wave is produced by making some part of the electric circuit large in dimensions. This enlarged part of the circuit is called the antenna. The antennas used in radio work, as is well known, often consist of long conductors supported on very high towers. The mechanism for producing a radio wave, therefore, is simply an enlarged or extended portion of an electric circuit in which an alternating current is made to flow. In the space near the antenna, alternations of electric pressure and of magnetic field are produced, just as alternations of air pressure are produced around a tuning fork. At any instant the electrical condition of the space around an antenna which is sending out radio waves could be shown by a diagram such as Fig. 5. The arrow on the line extending between the antenna and ground indicates that the electric pressure at a particular moment is in the direction indicated. When the current changes in direction, the direction of this electric pressure will be reversed and the electric pressure already mentioned will have handed on its effect to the surrounding space. Thus the effect of an



Fig. 5—Production of waves around an antenna.

electric pressure is handed on and spreads out through space, the direction of this pressure at any point is constantly alternating as the direction of the current in the antenna producing it alternates. The frequency of this alternation of the wave is the same as the frequency of alternation of the current in the antenna.

Lines of electric pressure alternating in direction are

thus constantly spreading out from the antenna just as the ripples spread out on a pond after a stone has been thrown into it. Something very similar to the ripples would be seen if, in some way, the alternations of electric pressure could be made visible and a person were to look down from above upon the antenna and the space around it. The waves of electric pressure spreading out and successively alternating in direction would look something like the lines shown in the upper part of Fig. 5. The waves spread out in all directions and go to great distances.

It at once suggests itself that the waves will produce an effect at a point far distant from the source if a means is provided at that point for converting the wave action into electric current in a circuit. In this way electric communication without connecting wires is established.

Nature of Radio Waves.—We cannot see electric waves, as we see ripples or the waves on a pond, but there is nothing specially mysterious about them. We can not see sound waves. If a tuning fork is struck, it gives off sound waves, which, starting at the tuning fork, travel out into the air in all directions like the ripples referred to. Sound waves are produced by the motion of the metal prong of the tuning fork. As the prong moves back and forth it causes the air next to it to move back and forth. This motion is handed on to the surrounding air and so moves out to a great distance in the air just as the ripple on the pond spreads out. The slight to-and-fro motion of the air spreading out in this manner is called a sound wave.

Electric waves also consist of a certain kind of to-and-fro motion. Just as the motion of the tuning fork causes alternating pressure in the surrounding air, similarly, whenever an alternating electric current flows in an electric circuit the to-and-fro motion of the current causes alternating electric pressure in the space next to the wire. This to-and-fro or alternating electric pressure in the space surrounding the wire affects the surrounding space and spreads out in exactly the same way as a sound wave in air.

The electric waves are also called radio waves, and it is by means of them that radio communication is carried on. It is an interesting fact that radio waves are really of the same kind as light waves. We are all familiar with light waves, and it should help to make radio waves less mysterious to know that they are both electric waves. The difference between light and radio waves is the frequency of alternation. Thus electric waves are much more common things than is sometimes supposed. Electric waves are used for many purposes, their use depending on the frequency of the waves. This is shown by the table on page 13

showing the frequencies of the various kinds of electric waves.

Wave Length and Frequency.—Frequency is the number of cycles per second, or the number of to-and-fro alternations of the electric pressure, as the wave travels out through space. Wave length is the distance from the crest of a wave to the crest of the next adjacent wave. Since all electric waves travel at the same velocity (186,000 miles per second, or 300,000,000 meters per second), the shorter the length of the waves the larger the number of them which will pass by a given point during a second. The length of the waves is numerically equal to their velocity divided by their frequency (number of cycles per second). That is,

$$\text{wave length in meters} = \frac{300{,}000{,}000}{\text{frequency}}$$

For example, a radio wave 600 meters long is caused by a current in a transmitting antenna having a frequency of 500,000 cycles per second.

Waves Produced by	Cycles per second
Commercial Alternating Currents	25 to 500
Ordinary Telephone Currents	16 to 3,000
Radio	10,000 to 30,000,000
Heat and Light	3,000,000,000,000 to 3,000,000,000,000,000
X-Rays	3,000,000,000,000,000,000

All of these waves travel at the same speed. These electric waves are of an entirely different nature from sound waves. Sound waves are not at all electrical; they consist of actual to-and-fro motions of the air particles and travel with a speed of about 1,000 feet per second. The speed at which electric waves travel is much greater than this; it is so great that the passage of any kind of electric wave is practically instantaneous. The various kinds of electric waves shown in the table are much alike in many ways but they have some characteristic differences. Thus, radio waves are different from light waves in that they go through ordinary walls of buildings and other obstacles which are opaque to light.

The waves are radiated and spread out more effectively the higher the frequency. The ordinary low frequencies used in the alternating currents which light our houses alternate very slowly. Such waves travel readily along wires. In order to get a wave which will travel effectively through space, higher frequences must be used; that is why the waves used in radio communication make a large number of vibrations per second.

It is to be noted that these frequencies are not, however, as high as the frequencies of light waves. Light waves travel in straight lines, which is one of their characteristic differences from low-frequency waves of alternating current power, which follow along wires. Radio waves are intermediate in character between the two, and can travel in straight lines and also travel along conducting wires.

The fact that radio waves, which are able to travel out into space without conducting wires, are of high frequency, is one of the important characteristics of radio communication.

Wave Reception.—Now think of what is happening at a distance from an antenna which is sending out waves. As the wave passes any point there is an alternation of electric pressure going on continuously at that point. The alternating electric pressure or wave action at that point could be illustrated by the wavy line of Fig. 6. The portions of the wave above the horizontal line correspond to the electric pressure in one direction, and the portions below correspond to

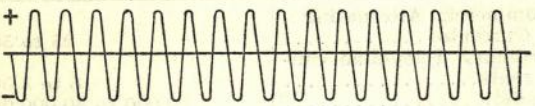


Fig. 6—Continuous wave.

the electric pressure in the other direction. This can be understood by thinking of a sound wave. As the sound wave passes out through the air, it will set in vibration any object which is capable of taking up the motion. Suppose, for instance, that a sound wave produced by a tuning fork passes a second tuning fork which is in tune with it, that is, having the same natural pitch or frequency of vibration as the first tuning fork. The to-and-fro motion of the air will start the second tuning fork into motion. This can be readily shown with two tuning forks, striking one of the forks, thus producing a sound wave. It can be proved that the second tuning fork is set into vibration by grasping the first with the hand so as to prevent its further motion. A sound from the second one can then be heard.

A radio wave can produce an effect at a distance in just the same manner. In any electric circuit the moving wave of electric pressure produces an electric current alternating with the same frequency as the wave. The moving wave is accompanied by a magnetic field, just as a current is. This moving magnetic field produces an electromotive force in any conductor across which it cuts, just as an electromotive force is produced by any other relative motion between a

conductor and a magnetic field. The electromotive force thus produced is what causes a current in the receiving antenna.

Comparison of Radio with Ordinary Wire Telegraphy or Telephony.—In the preceding sections the mechanism by which an electrical action can be made to affect a distant point without wire connection has been explained. The ether which fills all space can be considered to replace the wire connection. Thus, in wire communication there is a system as represented in Fig. 7, which shows a conducting wire line containing a source of varied current at one end and a detecting device (D) at the other end. In radio communication the wires are eliminated so that the corresponding simplified system would be as represented in Fig. 8, which shows the similar source of varied current and detecting device (D), each of these, however, being placed in a simple electrical circuit and the conducting wires between being eliminated. Both of these diagrams have been so greatly simplified that neither of them is really just like an actual telegraph or telephone system. Certain additional features must be used beyond what is shown in either Fig. 7 or Fig. 8 to carry on telegraphy or telephony. A species of telegraphy is possible by merely adding a key in either Fig. 7 or Fig. 8. Wire communication of this kind

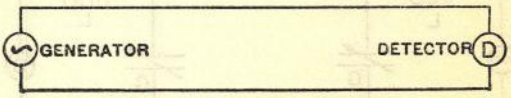


Fig. 7—Wire communication.

would thus be the use of an alternating-current generator as the source of power and a telephone receiver as the detector (D). The corresponding radio system would be the use of an alternating-current generator of high but still audible frequency together with the use of a telephone receiver in place of detector D. As a matter of fact, simple systems of just this kind are not

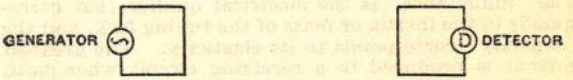


Fig. 8—Radio communication.

used because great advantages are secured by the addition of certain features which will now be discussed. Furthermore, these additional features not only improve radio telegraphy but are necessary for radio telephony.

Tuning.—The extremely simple system of radio communication indicated in Fig. 8 is not effective un-

less the alternating current used is of high frequency. Even then the current produced in the receiving circuit would be very small indeed unless the receiving circuit is in tune with the wave. That is, it must be arranged to respond to the frequency of alternation possessed by the first circuit and the wave which it sends out. This is just like what happens with the two tuning forks and the sound wave. The second tuning fork does not respond to the wave from the first unless the two are in tune. This can be shown by placing a bit of wax on one of the prongs of the second tuning fork, changing the pitch of that fork. When the first tuning fork is struck under these conditions it can readily be demonstrated that the second fork does not respond. In the same way the electrical arrangements in the receiving circuit which are used to receive radio waves must be such that the receiving circuit is electrically in tune with the radio wave. By this means the radio receiving circuit can pick out the particular wave which it is desired to receive and not be affected by other waves. This is fortunate because otherwise the interference between different radio messages would be hopeless. It would be just as though every sound wave which passed through the air set absolutely everything which it touched into vibration.

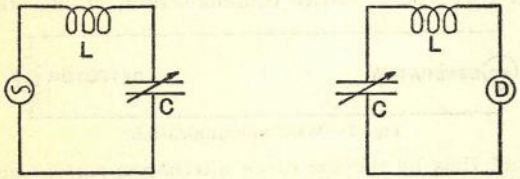


Fig. 9—Tuned radio circuits.

Just as the frequency to which a tuning fork responds depends upon its inertia or mass and its springiness or elasticity, the frequency to which the electrical circuit responds depends upon two corresponding electrical properties called inductance and capacity, respectively. The "inductance" is the electrical quality that corresponds to the inertia or mass of the tuning fork, and the "capacity" corresponds to its elasticity. The greatest current is produced in a receiving circuit when both the transmitting and receiving circuits are tuned—that is, arranged so that the product of the capacity and inductance is the same in each. The elements of a typical radio circuit are thus rather more complicated than shown in Fig. 8, which should be replaced by Fig. 9. The symbols C and L indicate the conventional diagrams for capacity and inductance. The device used to introduce capacity into a circuit is called a condenser, this usually consists of a pair, or two sets

of metal plates separated by air or by some solid non-conductor. The device used to introduce inductance into a circuit is called an inductor, or an inductance coil, or simply a coil; it is a coil of wire, as suggested by the usual diagram for an inductance.

Modulation.—We come now to a feature of radio which is often not understood. Anyone who will take the trouble to read this section ought, however, to gain a clear comprehension of the important subject of "modulation." As just mentioned, the frequency of alternation of radio waves is very high. It is so high, in fact, that a sound wave of such frequency could not be heard. Suppose, for instance, that an ordinary telephone receiver is used as a detector (D) in the circuit which is receiving a radio wave. Electric currents produced in a receiving circuit are of the same frequency as the wave frequency and tend to cause motions of the telephone receiver diaphragm. These motions are, however, of such great frequency that the diaphragm produces no audible sound. In order to permit the radio wave to be received and transformed into a sound, it is therefore necessary to break up the radio wave in some manner. This is done in radio telegraphy by interrupting the wave completely so

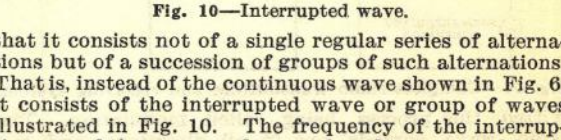


Fig. 10—Interrupted wave.

that it consists not of a single regular series of alternations but of a succession of groups of such alternations. That is, instead of the continuous wave shown in Fig. 6, it consists of the interrupted wave or group of waves illustrated in Fig. 10. The frequency of the interruptions or of the groups of waves is a frequency which is low enough to be heard. One of the ways of breaking the waves up into groups is by use of a "chopper," which is simply a rapidly rotating disc with contacts on it so as to alternately open and close the circuit.

This process of varying the high-frequency wave so that it is no longer a single regular series of alternations is called modulation.

Instead of breaking the wave up into simple groups of alternations, it is possible to modulate it, (*i. e.*, cause it to vary) in a manner which follows the sound variations produced by the human voice. It is thus possible to make a radio wave carry a voice wave. This is the process of radio telephony, and will be explained further in the next chapter.

Besides the reason given in a preceding section for the use of high frequency in radio, there is another

very powerful reason, which is connected with modulation. When it is desired to carry on telephony, it is necessary that the alternating current which produces the waves be of a frequency to which the sense of hearing does not respond. This is necessary because if the waves were of an audible frequency, the current which they produce in the receiving circuit would produce a sound that would be heard and would interfere with the voice or other sound which it was desired to hear. The wave frequency must therefore be so high that a sound wave of such frequency could not be heard.

Summary.—The principles of radio have been briefly explained in this chapter. They are few and simple. An electric wave is sent out into the air by means of electric current flowing in the transmitting antenna, the current being an alternating current of very high frequency. The high-frequency current (and consequently the wave it produces) is varied in accordance with the sound variations of the speech or other sound or signal which is to be transmitted, this process being called modulation. The radio wave spreads out in all directions, and can produce electric current in any electric circuit that is tuned to respond to the radio wave frequency. The way in which the current thus produced in radio receiving apparatus is converted back into sound is explained in the next chapter. The essentials of a complete radio transmitting and receiving system are shown in Fig. 11.

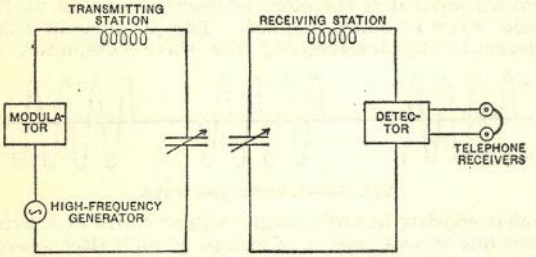


Fig. 11—Complete radio transmitting and receiving system.

Antenna: Converts radio wave into an alternating current of high frequency.

Inductance Coil: Forms, together with the antenna, a circuit which can be tuned to respond to the incoming radio wave. In this set it alone constitutes the "tuner".

Crystal Detector: Converts the alternating current in the antenna into a pulsating unidirectional current.

Telephone Receivers: Convert the pulsating unidirectional current into sound.

The functions of the parts of the two-circuit electron tube set as shown in Fig. 12, Chap. 2 may be summarized as follows:

Antenna: Converts radio wave into an alternating current of high frequency.

Primary Inductance Coil: Forms, together with the antenna, a circuit which can be tuned approximately to respond to the incoming radio wave. In this set it is the primary coil of the "coupler."

Series Condenser: Shortens the wave length to which the antenna responds. It also gives fine adjustment of the tuning of antenna circuit.

Secondary Circuit: Provides means of tuning more sharply to the desired wave than can be done by tuning in the antenna alone. It consists of the secondary inductance coil and the secondary condenser.

Secondary Inductance Coil: Couples the secondary circuit to the antenna circuit. It provides rough adjustment of tuning of secondary circuit.

Secondary Condenser: Provides fine adjustment of tuning of secondary circuit.

Electron Tube: Converts the alternating current in the secondary circuit into a pulsating unidirectional current and amplifies it.

Filament Battery (A): Supplies current to heat the filament of the electron tube.

Filament Battery Rheostat: Regulates current through the filament of the electron tube.

Plate Battery (B): Supplies current through the tube between plate and filament.

Telephone Receivers: Converts the pulsating unidirectional current from the electron tube into sound.

The functions of the several parts of the regenerative set shown in Fig. 13, Chap. 2 may be summarized as follows: All parts are the same as in the two-circuit electron tube set above except the following:

Tickler Coil: Feeds the effect of the current in the plate circuit back into the grid circuit so that the current is re-amplified.

Grid Condenser and Leak: Adjust voltage on the grid to a value giving sensitive action of electron tube as a detector.

Potentiometer Resistance: Provides fine adjustment of plate voltage.

Telephone Condenser: Provides path for radio-frequency current that is easier than through the telephone receivers.

The functions of the parts of the amplifier shown connected to a crystal detector set in Fig. 15, Chap. 2, and to an electron tube set in Fig. 16, Chap. 2, as far as not already covered above, are as follows:

Electron Tubes: Convert the small voltage and power applied to the grid into larger voltage and power in the plate circuit.

Amplifier Transformers: Convert the small voltage applied to the input side into a larger voltage on the output side.

Generators of Radio-Frequency Current.—Turning now to radio transmitting apparatus, the principal apparatus which is required is a generator of alternating current of radio frequency. There are numerous kinds of generators, but the kind used in radio telephony makes use of powerful electron tubes. These tubes have filament, grid, and plate, the same as the electron tubes used in receiving sets, but are larger and more powerful. (See Frontispiece).

The way in which electron tubes are used to generate current is a mere extension of their use in amplifiers. If, in Figure 8, the coils L_1 and L_2 are placed close together, the effect of L_2 on L_1, can become so great that the current continues to flow even if no signals are coming into the antenna to which the input circuit CL_1, is connected. The alternating current thus produced will have the frequency to which the circuit CL_1, is tuned. What happens might be expressed by saying that an amplifier can be made so powerful that no input current at all is required. This does not mean that it is a perpetual motion machine, because the power to operate it must be supplied by the battery that is connected in the plate circuit of the tubes. It does mean, however, that the electron tube can be used to generate alternating currents as well as to receive and to amplify them.

Apparatus for Transmitting Radio Telegraph Signals. The apparatus for transmitting radio telegraphy and telephony differ mainly in the arrangement by which the continuous current produced by the generating circuits is modulated or changed in strength to follow the dots and dashes of the telegraph code or the variations of the voice. Radio telegraph transmitting sets are the simpler. Means are provided to modulate the radio-frequency current at an unvarying audible

frequency. To signal it is only necessary to stop and start the current suddenly by means of an ordinary telegraph key which opens and closes the circuit. The inductance coils and condensers are of somewhat different design than the coils and condensers used in receiving sets. In transmitting sets the various parts of the circuit must carry considerably larger currents. The filaments of the electron tubes are lighted from storage batteries, as in receiving sets, but the "B" battery (battery in plate circuit) is replaced by a dynamo which will supply

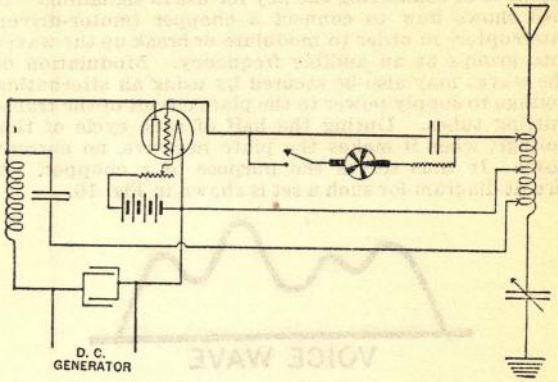


Fig. 9—Circuits of radio-telegraph transmitting set using chopper for securing modulated waves.

more power than is economically obtained from batteries. The voltage of this dynamo may be between 300 and 2000 volts. The power which it delivers depends upon

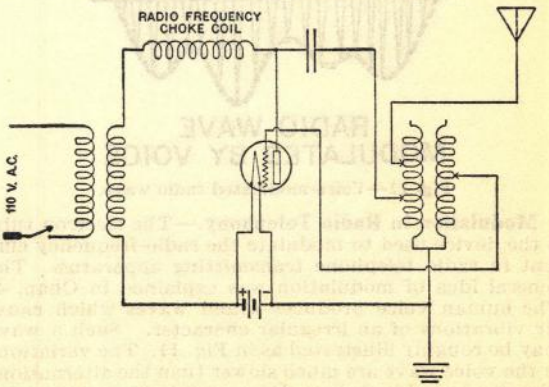


Fig. 10—Circuits of radio-telegraph transmitting set using alternating current for plate supply and modulation.

the type and number of electron tubes used in the transmitting set. The power of the set may be increased by using a larger electron tube or by connecting additional tubes to the circuit. In the latter case the grids of all of the tubes are connected together and the plates of all of the tubes are likewise connected together. The filaments are all heated by current from the same storage battery.

One type of radio-telegraph transmitting circuit is that shown in Fig. 9. This shows one of various methods of connecting the key for use in signalling. It also shows how to connect a chopper (motor-driven interrupter) in order to modulate or break up the waves into groups at an audible frequency. Modulation of the waves may also be secured by using an alternating voltage to supply power to the plate circuit of the transmitting tubes. During the half of each cycle of this voltage, when it makes the plate negative, no current flows. It thus serves the purpose of a chopper. A circuit diagram for such a set is shown in Fig. 10.

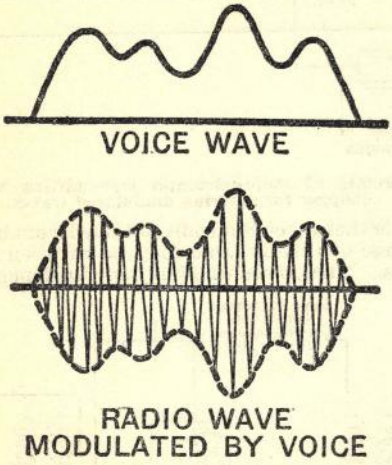


Fig. 11—Voice-modulated radio wave.

Modulation in Radio Telephony.—The electron tube is the device used to modulate the radio-frequency current in radio telephone transmitting apparatus. The general idea of modulation was explained in Chap. 4. The human voice produces sound waves which cause air vibrations of an irregular character. Such a wave may be roughly illustrated as in Fig. 11. The variations in the voice wave are much slower than the alternations of current used in radio. It is possible to make a radio wave carry a voice wave, and when this voice-modu-

lated wave is received it can be passed through a detector and telephone receiver and the voice heard just as radio telegraph signals are heard. The way in which the voice wave is super-imposed upon the radio wave is illustrated in Fig. 11. The alternations of the radio wave are shown by the full lines, and the dotted boundary lines show that the intensity of the wave has been made to vary in accordance with the sound wave produced by the voice. This wave can be received in exactly the same way as any wave in radio-telegraphy—no special apparatus is required for receiving radio telephony. The voice at the transmitting station is heard very clearly. It can be made as loud as desired at the receiving station by the use of amplifiers.

The radio wave is really modulated or molded just as a phonograph record is molded by a sound wave. The means by which this modulation is accomplished is the electron tube. If in Fig. 6 the telephone receiver is replaced by any kind of generator of radio-frequency current, then if a person speaks into a telephone transmitter connected between the grid and filament of the tube, the variations caused by the sound of the person's voice cause the intensity of the radio-frequency current in the plate circuit to vary correspondingly with the voice sound wave. The radio-frequency current is thus not of constant amplitude but varies in amplitude in accordance with the voice, Thus a modulated radio wave as in Fig. 11 is produced.

Radio Telephone Transmitting Apparatus.—The circuit of a radio telephone transmitting set is similar to that of a radio telegraph transmitting set except for

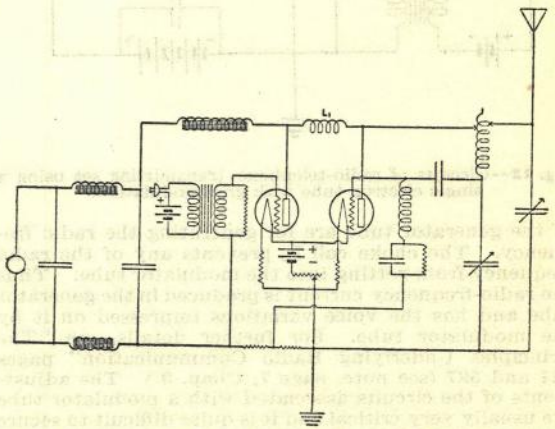


Fig. 12—Circuits of radio-telephone transmitting set using one generator tube and one modulator tube.

the modulating device. A diagram of a complete set is shown in Fig. 12. Here the microphone, into which the speaker talks, is connected through a suitable transformer to the grid and filament terminals of an electron tube. This tube on account of this use is called the modulator tube. The plate current from this tube varies according to the sound-wave variations of the voice. The plate current of the generator tube, which is to the right of the modulator tube, has variations corresponding to those of the modulator tube because there is a choke coil in the lead from the generator (at the left) which keeps the sum of the direct current supplied to the plate circuits of the two tubes constant. The arrangements of coils and condensers to the right

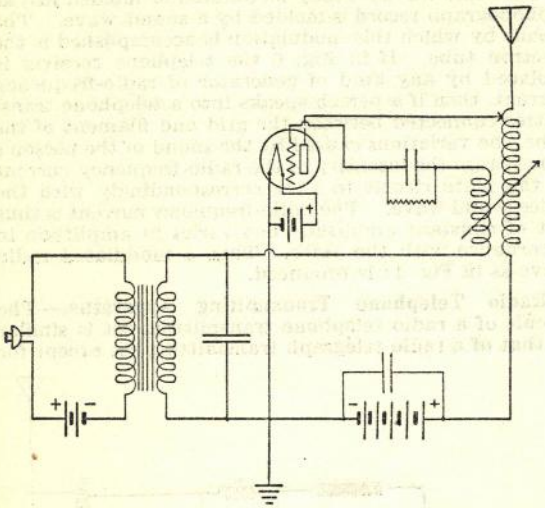


Fig. 13—Circuits of radio-telephone transmitting set using a single electron tube with grid modulation.

of the generator tube are for generating the radio frequency. The choke coil L_1 prevents any of the radio frequency from getting into the modulator tube. Thus the radio-frequency current is produced in the generator tube and has the voice variations impressed on it by the modulator tube. For further details, see "The Principles Underlying Radio Communication" pages 521 and 527 (see note, page 7, Chap. 3.) The adjustments of the circuits associated with a modulator tube are usually very critical and it is quite difficult to secure accurate production of current which varies in exactly the same way as the sound waves of the voice.

A somewhat simpler circuit arrangement, in which a single tube serves as both generator and as modulator. is that shown in Fig. 13. It is even more critical in adjustment but is sometimes used where a low-power transmitting set with a simple circuit arrangement is desired.

Continuous-Wave Radio Telegraphy.—While considerable stress has been laid in all these explanations on the process known as modulation, the reader should know that there is a system of radio telegraphy in which there is no modulation. This should be kept apart, however, in thinking on radio, as it is done by distinctly different processes. There being no modulation, the wave is simply an unvaried continuous wave of radio-frequency. A circuit diagram of a continuous-wave transmitting station is given in Fig. 14. The bare essentials of this diagram are given in Fig. 8. For

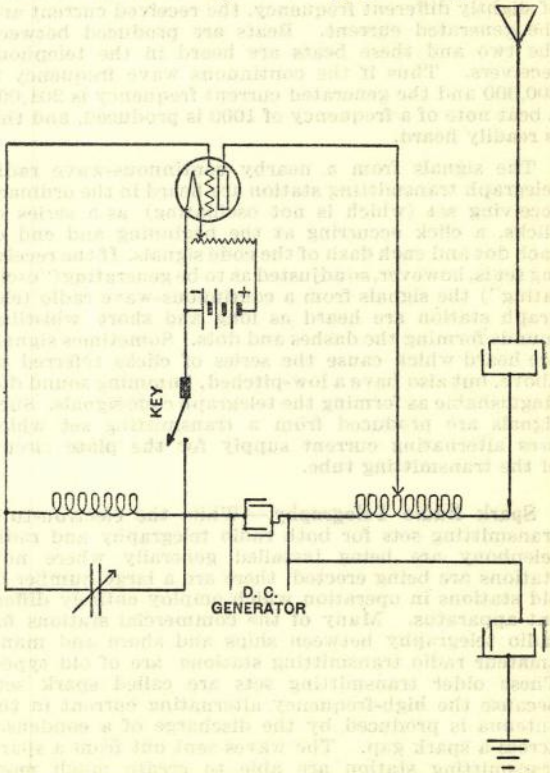


Fig. 14—Circuits of continuous-wave radio telegraph transmitting set.

further explanation of the features of circuits like Fig. 14 see "The Principles Underlying Radio Communication," pages 491 to 498 (see note, page 7, chap. 3).

A "continuous wave" would not be heard in the ordinary receiving set, because as already explained the frequency of radio waves is so high that the human ear does not react to a sound of such high frequency. These continuous waves are received by an ingenious scheme. In the ordinary regenerative receiving set, the coupling of the "feed back" from the plate to grid is increased until the circuit begins to generate ("oscillate"), as explained on page 12 under "Generators of Radio-Frequency Current." The condenser is adjusted until the circuit is tuned to a frequency just a little different from that of the received continuous-wave current. There are thus present two high-frequency currents of slightly different frequency, the received current and the generated current. Beats are produced between the two and these beats are heard in the telephone receivers. Thus if the continuous wave frequency is 200,000 and the generated current frequency is 201,000 a beat note of a frequency of 1000 is produced, and this is readily heard.

The signals from a nearby continuous-wave radio telegraph transmitting station are heard in the ordinary receiving set (which is not oscillating) as a series of clicks, a click occurring at the beginning and end of each dot and each dash of the code signals. If the receiving set is, however, so adjusted as to be generating ("oscillating") the signals from a continuous-wave radio telegraph station are heard as long and short whistling sounds forming the dashes and dots. Sometimes signals are heard which cause the series of clicks referred to above, but also have a low-pitched, humming sound distinguishable as forming the telegraph code signals. Such signals are produced from a transmitting set which uses alternating current supply for the plate circuit of the transmitting tube.

Spark Radio Telegraphy.—While the electron-tube transmitting sets for both radio telegraphy and radio telephony are being installed generally where new stations are being erected, there are a large number of old stations in operation which employ entirely different apparatus. Many of the commercial stations for radio telegraphy between ships and shore and many amateur radio transmitting stations are of old types. These older transmitting sets are called spark sets because the high-frequency alternating current in the antenna is produced by the discharge of a condenser across a spark gap. The waves sent out from a spark transmitting station are able to create much more interference than the waves sent out from a well-

designed electron-tube transmitting station. A diagram showing the circuit used by a spark transmitting set is that given in Fig. 15. An alternating-current generator is connected to the primary of a transformer whose secondary circuit supplies an electric charge to a condenser. This condenser discharges through the inductance coil P and the spark gap. This produces a corresponding current in the inductance coil S of the antenna circuit. There results a series of trains of waves which are called damped waves.

For a further study of the principles of radio transmitting and receiving apparatus, the reader is referred to "The Principles Underlying Radio Communication," Chapters 5 and 6. (See note, page 7, Chap. 3).

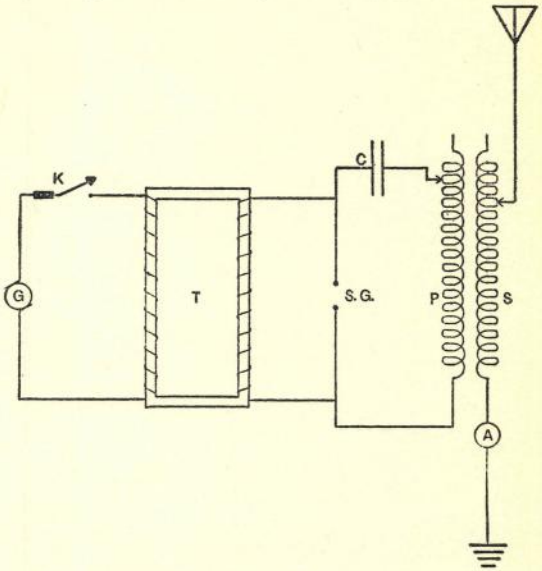


Fig. 15—Circuits of spark type of radio telegraph transmitter.

A—Ammeter measuring radiated energy.
C—Condenser.
G—Alternating-current generator.
K—Operating key.
P—Primary of inductance coil.
S—Secondary of inductance coil.
S. G.—Spark gap.
T—Transformer.

CHAPTER FIVE

PRINCIPLES OF RECEIVING AND TRANSMITTING APPARATUS

In chapter 4 an explanation was given of the general processes by which radio is carried on. The present chapter explains the action of the various parts of the apparatus used. It gives the "how" or "why" of the devices whose operation was described in Chap. 2. A few paragraphs are also devoted to transmitting apparatus, for the general information of the user of receiving apparatus. This book does not attempt a complete discussion of transmitting apparatus.

The Antenna.—The radio waves are produced by alternating current which flows in the circuits of the transmitting station, and these waves are converted back into alternating current in the circuits of the receiving station. That is, electrical vibrations produce electric waves which spread out in all directions and these waves are capable of producing electrical vibrations again in any circuit which they pass. The device which converts the electric vibrations (alternating current) into electric waves, or which converts the waves back into alternating current is the antenna. The antenna really has a large job to do, and for all that, it is nothing but a piece of wire.

The antenna is simply an enlarged portion of the circuit. As previously explained, radio circuits consist of two principal elements, called capacity and inductance. A circuit containing capacity and inductance naturally responds to some particular frequency of alternation of electric current, just as a vibrating bell or tuning-fork has some natural frequency of vibration. The "capacity" is the electrical quality that corresponds to the elasticity or springiness of the tuning-fork, and the "inductance" corresponds to its inertia or mass. Now the antenna can be either one of these two elements, the capacity or the inductance. In most radio stations, it is the capacity. It consists essentially of two electrical conductors with air between. One of these conductors is an elevated wire, or set of wires, while the other conductor can be either a similar set of wires or else the ground. A typical circuit in which the antenna thus constitutes the capacity is shown in Fig 1. The other part of the circuit, the

inductance coil, is connected between the elevated wires and the ground.

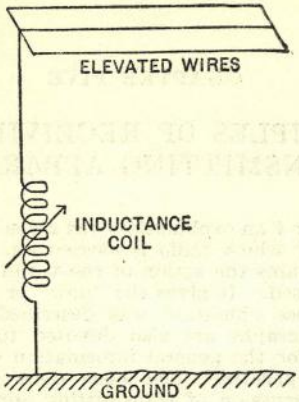


Fig. 1—Simple antenna circuit, with elevated wires and ground constituting a capacity

Just the opposite arrangement is used with a "coil antenna." The inductance coil is made large and constitutes the antenna, and a device possessing capacity (called a condenser) is connected to the two ends of the inductance coil. The arrangement is shown in Fig. 2. The "condenser" consists of two metal plates, or sets of plates, with air or some other non-conductor between.

The simple antenna consisting of elevated wires together with a ground connection is much more commonly used than the coil antenna. The reason is that it gives more powerful signals. For special purposes, however, the coil antenna has advantages, especially in a receiving station. It can be very small, so that a complete radio receiving station can be within an ordinary room. Also, the strength of the signal received on it depends on the direction in which the coil is turned. By turning the coil, therefore, one can determine the direction from which the wave is transmitted. A coil antenna is thus a radio direction finder, it is useful in steering ships and airplanes, and also enables one to prevent interference by turning it so as not to receive the signals from a disturbing station.

Tuning and Coupling.—As explained in the last chapter, radio receiving apparatus must be so adjusted as to be in tune with the wave to be received. The alternating current produced in the receiving circuit will be greater the more nearly this circuit responds to the particular frequency of alternation that the wave has. The circuit is adjusted to respond best to the

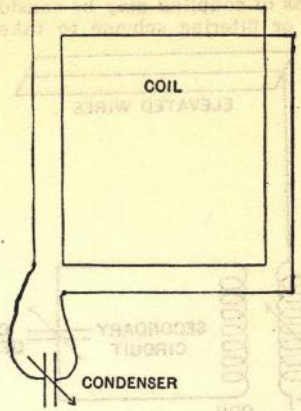


Fig. 2—Coil antenna circuit.

wave by varying either of the two elements, the capacity or the inductance. The process of adjusting the capacity or the inductance is called tuning. When the antenna constitutes the capacity, as in Fig. 1, the tuning is done by means of varying the inductance, and *vice versa* when the antenna is the inductance coil as in Fig. 2 the tuning is done by varying the capacity of the condenser.

The diagrams shown in Figs. 1 and 2 are the foundations of all radio circuits and deserve careful study. Figure 1 in particular should be thoroughly understood, because most radio apparatus is designed for use with the elevated-wire antenna.

Tuning has another object besides getting the strongest possible response from the wave that it is desired to receive, and that is to avoid receiving any other waves of different frequency or wave lengths. It has been found that this is greatly helped by adding another circuit which is also tuned in the same way as the first circuit. The additional circuit also consists of capacity and inductance, and is called the secondary circuit. The process by which it is connected to the antenna circuit is called "coupling." One method of coupling is shown by the diagram in Fig. 3. The inductance coil of the secondary circuit is simply placed close to the inductance coil of the antenna circuit. The magnetic effect of the latter coil gives rise to a current in the other coil. The condenser in the secondary circuit is varied until maximum current is produced. The amount of this current depends also on the position of the two coils with respect to each other.

The process of coupling may be considered as a sort of straining or filtering scheme to take in the wave

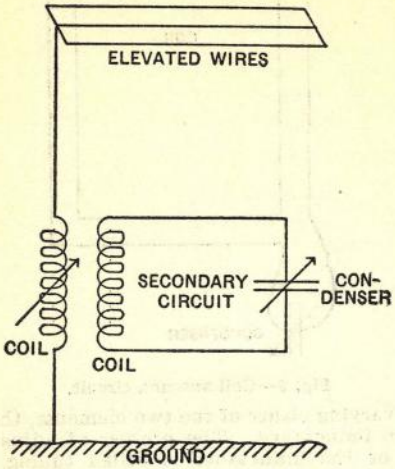


Fig. 3—Coupled circuits to improve tuning.

desired and exclude others. The antenna circuit filters out the wave desired to a certain extent, by the process of tuning. This is passed on to the secondary circuit which filters once again, thus refining or purifying the received wave still further.

The Detector.—Besides receiving the radio current in an antenna and adjusting the circuits so that the current is as great as possible, there yet remains something to be done before it becomes possible to translate the received radio current into a sound that can be heard in the telephone receiver. When one of the groups of alternations shown in Fig. 10, chap. 4 acts on the telephone receiver it causes no motion of the diaphragm because each variation of the current in one direction is immediately followed by the current in the opposite direction so that the resulting effect of the group of waves upon the telephone receiver diaphragm is no motion at all. It is therefore necessary, in order to convert the current into a sound, to use something else with the telephone receiver. This something else must be such as to make the current flow through the telephone receiver in only one direction. It must allow the electric current to flow through it in one direction and stop current which tries to flow through it in the opposite direction; that is, it must be some sort of electric valve. The effect of such an electric valve, may, perhaps be understood more clearly by taking a sheet of paper and placing it upon Fig. 10, chap

4, so as to block out the lower half of the waves shown. This leaves only the upper halves of the little groups of waves and this is exactly what the electric valve does. The thing which acts as an electric valve is called the detector. Using it, successive impulses of current flow through the telephone receiver and all of these tiny impulses in any one group add their effects together and produce a motion of the telephone diaphragm.

Crystal Detector.—The simplest detector is a piece of crystal with a fine copper wire in light contact with it. (There are variations from this, sometimes two crystals in contact are used). The crystal most commonly used is galena (lead sulphide). At the contact between the crystal and metal, current can flow in one direction but not in the other. When connected to a circuit, therefore, in which alternating current is flowing, it allows only the current impulses in one of the directions to flow through it. It thus has the electric valve action of which we have been speaking.

Electron Tube.—The most satisfactory and sensitive detector is the electron tube. This remarkable device, as will be shown, is not only useful as a detector but also as a high-frequency generator, as a modulator, and also as an amplifier by means of which the currents are more readily controlled and utilized. It is very satisfactory and stable in operation for all these various purposes. The basic principles of action of the electron tube are now discussed. For further study, the student is referred to "The Principles Underlying Radio Communication." Chapter 6. (See note, page 7, chap. 3).

The electron tube is a very simple device which looks more like an ordinary incandescent lamp bulb than anything else. While experimenting in the development of the incandescent lamp Edison made the discovery that an electric current could be made to flow in the empty space inside the bulb near the hot filament. If a metal plate is placed inside of an incandescent lamp bulb near the filament (Fig. 4) and if by means of a wire through the glass this metal plate is connected by wire through a battery and an indicating instrument to the filament, a current will flow as indicated by the instrument. A current is flowing in the wire and also flowing across the empty space between the filament and the plate. By much patient scientific research, scientists have found that this current taking place in the lamp consists of the flow of a stream of very small electric particles called electrons. These electrons are shot out into the surrounding space in all directions by the hot filament. The electrons may be said to fill the bulb like a vapor. They move at random in all directions unless there is an electric force to make them move in some particular direction. The battery connected in the circuit outside the bulb

supplies an electric force which acts between the filament and plate and makes the electrons move from the filament to the plate. If the battery is disconnected, there is no current, and as many electrons as strike the plate fall off again into the bulb. The current depends on the number and speed of the electrons. The battery is what gives them their speed in the direction from filament to plate. The battery

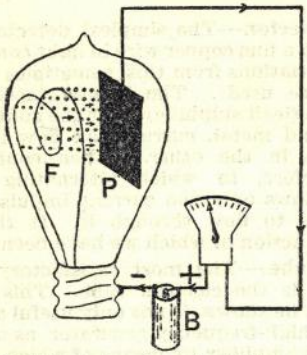


Fig. 4—Use of electron flow from hot filament (arrows show direction of electron flow, the reverse of the conventional direction of current).

performs much the same action as a steam pump would if the bulb were a room into and out of which steam pipes were connected. If the pump were disconnected, there would be no flow of steam, and when the pump is connected, steam is made to flow into and out of the room and through the pipe.

The point of all this is that the electron flow in the bulb has a sort of valve action. The electrons are shot out from the very hot filament and can be made to flow toward the plate by connecting a battery in the proper direction. If the connections of the battery are reversed, however, no current will flow because there is no such emission of electrons from the plate, which is cold; the electric force produced by the battery in this case has nothing to work on and can do nothing except prevent the flow of electrons out of the filament to the plate. It should be clearly understood before going further that the action of the electron tube thus depends upon the fact that an electric force can be applied in one direction which causes an electric current from the filament to the plate, but that if this electric force is reversed no current flows. The device gives exactly the rectifying action needed in order to make the received signals in radio produce sound in a telephone receiver. Suppose that the bulb shown in Fig. 4 is connected to a radio receiving circuit in place of the battery. Suppose also that the indicating instrument

is replaced by a telephone receiver. This is shown in Fig. 5. The pulses of current in the receiving circuit similar to those of Fig. 10, chap. 4, produce electric force inside the bulb between the filament and plate which alternates in direction just as the pulses of current do. On account of the rectifying action, current can flow through the bulb only in one direction, and consequently

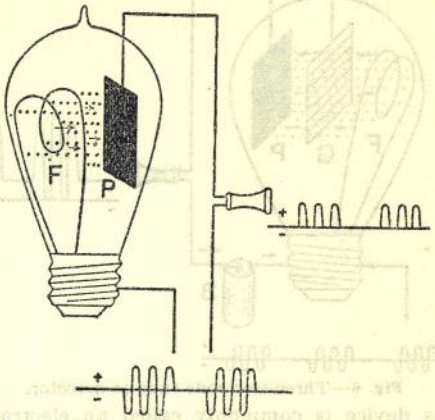


Fig. 5—Showing principle of detector action.

the pulses of electric force in one direction only are effective. As a result, pulses of current flow through the telephone receiver in groups, the pulses being all in one direction. This causes a note in the telephone receiver, as already explained.

The Purpose of the Grid.—An improvement in the original electron device was made by L. De Forest which very greatly extended its power and usefulness. As shown in Fig. 6, a grid of very fine wire is placed in the tube between the filament and the plate. The grid is placed closer to the filament than to the plate. The electrons which are emitted by the filament can move freely between the grid wires. If by means of a battery or something else an electric force is established between the filament and the grid, this electric force causes electrons to move away from the filament toward the plate, and since the grid is placed much closer to the filament, the electric force makes the electrons move much faster than would the same electric force between the filament and plate. Very few of the electrons are taken by the grid, and a very small current thus goes through the wire connected to the grid. Thus a very small current to the grid controls the flow of a much larger current to the plate. Hence a larger current can be taken out of the tube

than is put into it. A small electric force acts between grid and filament, causing a large electron flow from filament to plate. There results a relatively large flow of current in the apparatus connected outside the tube between the plate and filament.

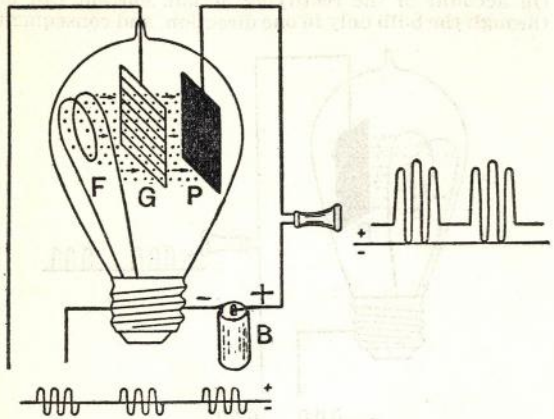


Fig. 6—Three-electrode tube as detector.

This device is commonly called an electron tube. (It is also known by many other names, as vacuum tube, audion, triode, and radiotron.) It magnifies or amplifies electric currents. It accomplishes the control of a large amount of power by a small power. This is just the same thing that a gun does—pressing the trigger several times in a repeating pistol is like the action of the tube with successive pulses of electric force. The grid corresponds to the trigger, and the plate to the gun barrel.

Electron tubes which are used as detector tubes ordinarily have a slight amount of gas remaining inside. These are more sensitive than the highly evacuated tubes used as amplifier tubes, but they require more careful adjustment of the current which lights the filament and of the voltage of the battery connected to the plate circuit. On account of the fact that the adjustments are not so critical when amplifier tubes are used, many operators prefer to use them as detector tubes.

Amplifier.—On account of the control of the plate current by a smaller grid current, the electron tube makes possible some very wonderful things.

It is perfectly possible and quite easy to take the magnified output from an electron tube and pass it into a second electron tube, using that to make a still further amplification of the current. Using one tube after another in this way, we obtain what is called an

amplifier. Two tubes joined together in this way are shown in Fig. 7 and the process can be repeated several times, using a number of tubes. The current is increased by each tube and handed on to the next without any change or distortion of the current even though it passes through several stages.

Fig. 7 is only schematic. It is not possible, in actual practice, to run the connection directly from the plate of one tube to the grid of the next tube. The reason is that there must be a battery connected between plate and filament, and the battery must not be in the grid circuit. The battery is required to make the electrons flow to the plate, while the function of the grid is to introduce variations of the electron flow in its tube. Consequently there must be some device inserted between the two tubes which allows the battery to be inserted in the plate circuit of the first tube and passes on into the second tube only the altering or varying voltage which constitutes the signal which it is desired to amplify. This device may be a transformer or a resistance combination as described in Chap. 2, page 23.

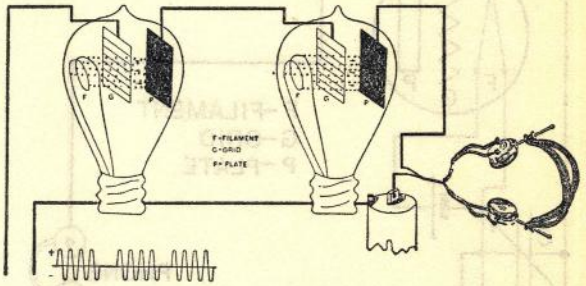


Fig. 7—Principle of the amplifier.

The amplifier is of the greatest importance in radio and in long-distance wire telephony. It reduces the amount of power that must be used in a radio transmitting station because when an amplifier is used in a receiving station, signals can be received which are far too feeble to be received without an amplifier. By means of amplifiers to which are connected loud-speaking telephones, speeches are made fully audible to all persons in a very large crowd. The large announcers used in railway stations now make use of amplifiers. By means of amplifiers, submarine vessels can receive radio messages when entirely submerged.

Regeneration.—An electron tube may act as a detector and an amplifier simultaneously. That is, the output from the detector tube, instead of being connected to a second tube, may be connected back to the input of the detector tube itself. The current is

then amplified in the tube and the process repeats itself. This results in enormous increase in the sensitiveness of the detector. The process of feeding back the output to the input circuit is called "feedback" or "regeneration," and the principle is shown in Fig. 8. The radio-frequency input circuit consisting of the (coil of wire) inductance L_1 and the (condenser) capacity C is connected to the grid and filament of the electron tube. Between the plate and filament there is connected, besides the telephone receivers and battery, the inductance L_2. This is placed close to the inductance L_1, and the magnetic field caused by the current in it, reacts on L_1, increasing the current in it. This current in L_1, then flows to the grid and is amplified in the tube. The amplified current flowing in the inductance L_2 again reacts on L_1, and so the process is repeated over and over. These repetitions are simultaneous, and the net result is very greatly increased output current in the

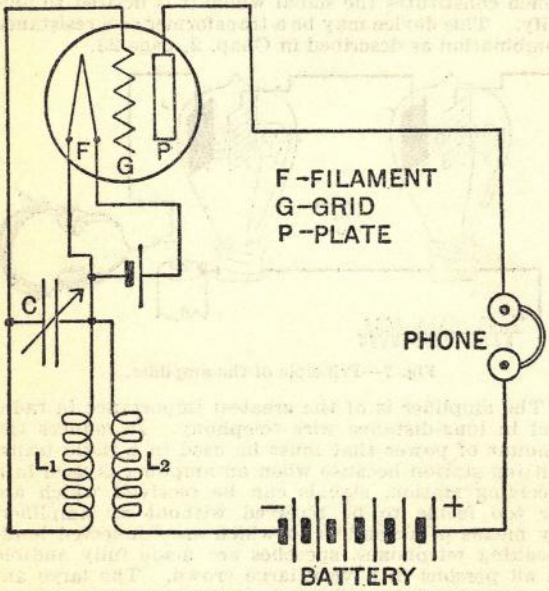


Fig. 8—Schematic diagram of regenerative amplifier.

plate circuit and hence in the telephone receivers. There are other methods of connection, but the principle is the same.

Summary of Functions of the Various Parts of Typical Receiving Arrangements.—The functions of the several parts of the simple crystal detector set shown in Fig. 9, Chap. 2 may be summarized as follows:

CHAPTER SIX

LINES OF ADVANCE IN RADIO

Elimination of Antenna and Battery.—The radio receiving apparatus now in use in the homes has been taken over without much change from the rough and complicated type of apparatus used on ships. The first automobiles were merely wagons with engines placed in them and they had a whipstock on the dashboard. It is just as incongruous to take a storage battery into a living-room. Methods have been worked out to eliminate the storage battery. Receiving sets are already on the market that use small dry batteries in place of the storage battery. Methods for replacing the batteries entirely by connection to the alternating-current lamp socket are also known; they will doubtless shortly be manufactured and on sale.

Strictly speaking, it will never be possible to eliminate the antenna. There must always be something to receive or catch the wave and convert it into a current. Nevertheless the antenna can be made so small or in such a form that it will be as good as eliminated. As a general principle, when smaller forms of antenna are used it is necessary to have more sensitive amplifiers. One such small antenna is the coil antenna, which was explained in chapter 5, and which is mentioned again just below under "Direction Finding." Another way out is to use a mass of metal within the house, such as a metal bed, as the antenna. The same effect is attained by a connection to the electric wiring in the house as an antenna. A special connecting plug has to be used, so as to avoid short-circuiting the wiring; it is best for amateurs not to try this. All these schemes for eliminating the antenna will be more and more successful as receiving apparatus, already extraordinarily sensitive, is further improved and more widely used.

Direction Finding.—In chapter 2 it was explained that a coil antenna is directional. That is, it receives signals from stations which are in line with its plane and receives practically no signals from stations which are in a direction at right angles. This property of coil antennas is being used to an increasing extent as a method of eliminating the interference which is caused by the working of a number of broadcasting stations on practically the same wave lengths. In order to accomplish this the coil should be turned about

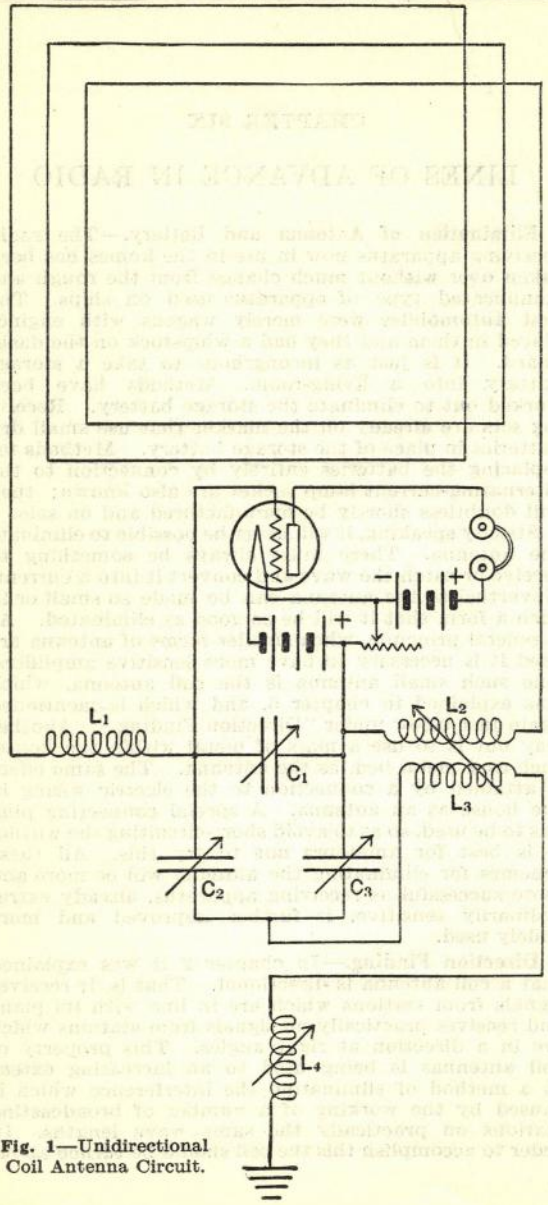


Fig. 1—Unidirectional Coil Antenna Circuit.

a vertical axis until its plane is at right angles to the station whose signals it is desired to eliminate. It will then be possible to hear stations which are in any direction within 30 or 40 degrees of the direction in which the plane of the coil lies, but nothing will be received from stations in a direction of 90°.

The coil antenna receives equally well from two opposite directions. Recent studies have indicated that it is possible to arrange a circuit which will receive from one direction to the exclusion of signals from the opposite direction. Fig. 1 shows a circuit which may be used for this purpose. Other methods are possible and it is to be expected that further experiments with combined coils and elevated antennas will greatly improve this unidirectional reception.

Sometimes it will be found that the minimum indication of a direction finder is not very sharp, but that weak signals can be heard no matter in what position the coil is turned. One cause for this may be a lack of symmetry in the capacity of the two ends of the coil to ground or to the nearby metallic base. Remedies are being developed for such troubles. One remedy is to connect a "balancing condenser" as shown in Fig. 1. This is simply a variable condenser with two sets of fixed plates and one set of moving plates, the moving set of plates being connected to the ground or to one side of the filament ("A") battery. Sometimes even the adjustment of this condenser will not secure a sharp minimum. It is then likely that the waves in the immediate vicinity of the receiving station are bent from their normal position by the proximity of electric power wires, telephone wires, or metal structures. It is an interesting experiment to take a small coil antenna and rotate it in an effort to find the position in which it receives loud or weak signals.

The coil antenna shown in Fig. 1 and the tuning condenser C_1, are of ordinary design and construction, as described on page 11 of Chap. 3. For example, the coil may consist of 6 turns of wire on a frame 5 ft. square and the condenser may be a variable air condenser having a maximum capacity of 0.001 microfarad. The three upper coils, L_1, L_2 and L_3, may have an inductance of the order of 100 to 1000 microhenries. The entire circuit, with the exception of the coupling of L_2 and L_3 should be arranged symmetrically. The lower coil, L_4, should have the proper inductance to tune the antenna to ground circuit to the wave length of the signals which it is desired to receive. An inductance of several millihenries is likely to be required, since the capacity to ground of the wire forming the coil antenna is ordinarily quite small. Instead of using the specially constructed balancing condenser, two variable air condensers may be used, as shown at C_2 and C_3. These may each have a maximum capacity of about 0.0002 microfarad.

Radio-Frequency Amplifiers.—One of the newer types of receiving apparatus referred to in chapter 2 is the radio-frequency amplifier. Since radio-frequency amplifiers are connected to the circuit between the receiving tuner and the detector they may also be tuned to the frequency or wave length of the radio signals. This gives an added opportunity for the elimination of wave lengths which it is not desired to receive. By using several stages of radio-frequency amplification, and two or three stages of audio-frequency amplification, it is possible to secure very loud signals without producing the disturbing note in the telephone receiver which is produced because of self generation of audio-frequency current when a large number of stages of audio-frequency amplification are used. When it is desired to use radio-frequency amplification with sharp wave-length tuning, transformer coupling should be used between the stages of the amplifier. If it is desired to secure rather broad tuning of the radio-frequency amplifier, it is desirable to use resistance coupling between the stages. However, resistance coupled amplifiers seldom give full amplification at frequencies above 300,000 (wave lengths below 1000 meters). For radio-frequency amplification at higher frequencies an interesting method is to have a local generating set which is coupled to the antenna circuit and which produces current of a frequency slightly different from the frequency of the signals to be received. This arrangement of apparatus is called a "heterodyne." The difference between the frequencies of the received and locally generated current should be about 100,000 cycles. Suppose the incoming wave has a frequency of 3,000,000 and the heterodyne is adjusted to give a frequency of 3,100,000, then the difference between these frequencies will be a beat current having a frequency of 100,000. This beat current can then be amplified with a radio-frequency amplifier. The output of the radio-frequency amplifier can then be treated as in the usual methods of reception. It can be detected and amplified at audio-frequencies or can be made audible by a second heterodyne. This method requires critical adjustments and considerable skill in manipulation. For further information on this method of reducing the radio frequency by the beat method, reference should be made to a paper by E. H. Armstrong, published in the Proceedings of the Institute of Radio Engineers, volume 9, page 3, 1921.

Line-Radio Communication.—It has been found that radio waves can be guided along wires between the transmitting and receiving stations instead of being radiated through space. The wires used in this way can be used simultaneously for ordinary telegraphic messages and telephone conversations, or for transmitting electric power. Various names have been

applied to this method of communication, such as "wire-radio telephony," "carrier-frequency telephony," "guided-wave telephony," and "wired wireless." Line radio telephony can be conducted by connecting a radio telephone transmitting set to one end of a wire in the same way as it ordinarily is connected to an antenna. The receiving set should be connected to the other end of the wire in a similar manner. Distances of 10 or 20 times the radio transmission ranges can be obtained with the use of a given power by this method. In connecting transmitting or receiving sets to the wire lines in this way care should be taken not to make any changes in the circuit which would affect other ordinary use. While the use of this method of communication is rapidly being extended, it is desirable that installations be made only by experts on account of the danger of interrupting the normal service of the wire lines or making wrong connections which would cause serious injury or damage.

Line radio telephony offers the additional advantage of carrying a number of messages over one pair of wires at the same time without interference. This is done by tuning arrangements at both the transmitting and receiving ends, which keep the different messages from interfering with one another. Waves guided along conductors seem bound to become more common, since trolley wires, power wires or any other sort of wires may be used to guide the waves. Thus a telephone becomes possible for every building into which electric light wires run. Furthermore, line radio telephony may be linked with or connected to ordinary wire telephony. Thus it seems unquestionable that this method will more and more supplement the regular telephone system.

While this is not really radio communication, it presents a solution to some of the problems of radio. It is a secret method of communication whereas radio is utterly public. It solves the question of communication in one direction to the exclusion of others wherever there is a guiding conductor in the direction desired.

Strays.—Attention has been called in chapter 2 to the occurrence of noises in the receiving set which are caused by atmospheric electrical disturbances ordinarily called "strays" or "static." Strays are the most serious limitation on radio communication at the present time and many methods have been devised for the purpose of minimizing their effect or increasing the strength of desired signals without increasing the strength of the undesired strays. So far none of these methods have proven to be satisfactory in the elimination of strays. The most useful means which have been developed for approaching a satisfactory solution are the use of a low directional antenna and the use of loose coupling between several sharply tuned circuits

of the receiving set. For receiving continuous waves the use of the beat method of reception is also a great advantage, but this is not applicable to radio telephone reception. The elimination of the effect of strays on radio receiving apparatus is a very important problem; it is almost as difficult as devising a method which would keep a tuning fork from vibrating when it is struck by a sledge hammer while permitting it to vibrate when it is placed in the vicinity of another tuning fork vibrating at the same pitch.

Elimination of Spark Sets.—It is desirable that the waves from a transmitting station be as nearly of a single frequency as possible. Most spark transmitting sets fall far from this requirement. As advances take place in radio and as new stations are installed these old types of spark sets will doubtless go out of use. If all the spark sets now used by ships and commercial stations and by amateurs are some day replaced by transmitting sets which will send out continuous waves, the objectionable interference in the form of dots and dashes, which many receivers of broadcast service meet at the present time, will be eliminated.

Loud Speakers.—It is often desirable that the radio telephone service obtained at a receiving station be made loud enough to be heard by a large audience or at least a room full of people. In order to accomplish this some form of loud speaker or loud speaking reproducer is attached. Many of the present types are adaptations of the ordinary telephone receiver which is designed for comparatively weak signals and does not operate well when forced to produce loud sounds. The result is that the speech or music is impaired in quality. There are, however, a number of scientifically designed loud speakers now available capable of giving very true reproduction.

Secrecy.—At present practically all radio transmission is of such a nature as to make it impossible to keep it from being received by anyone who so desires. The law forbids the disclosing of a message to other persons than those for whom it is intended. This of course does not cover the broadcast services, for the term is to signify transmission which is intended for an unlimited number of receiving sets without charge at the receiving end. Technical methods are being developed which will make it impossible for persons to receive certain kinds of radio signals unless supplied with a special kind of receiving apparatus which is designed to match with the particular transmitting set employed. By the use of such methods unauthorized listening-in will become so difficult as to be accomplished only by persons who are experts. It is not likely, however, unless technical developments are carried very much farther than seems at all possible at

the present time, that secrecy and selectivity will be obtained to such an extent as to make feasible the simultaneous secret communication between every pair of individuals who may desire to talk with one another.

Remote Control by Radio.—With the development of amplifiers there has come the increasing possibility of using radio to control the operation of any machinery or motion at a distance, by use of a relay or switch connected to special radio receiving apparatus. In order to accomplish this, signals are transmitted by radio and are received by a receiving station employing a very sensitive amplifier and specially designed relay device. This relay is then connected to such mechanism as it is desired to operate at the receiving station. Such mechanism may be an electric light, an electric bell, the control lever of an airplane, the switch of an electric power line, or other mechanism. A disadvantage of radio control is that the receiving apparatus must be in continuous operation with consequent consumption of power from the batteries or generator which supplies current to the receiving set. For certain purposes, however, this is not too great an expense to keep the use of distant control by radio from being feasible. The use of radio in this way is being considered by a number of electric power companies for operating switches at distant power plants or stations.

Regulation of Broadcast Service.—In order that the public may have a really satisfactory broadcast service, which it is possible for it to receive and which it will demand as the utility of radio broadcasting becomes further known, it is necessary that this service be under careful supervision. Its control or regulation must be in the hands of the Federal Government, since, by its very nature, radio extends in all directions and knows no boundaries. Through suitable advisory channels the public can inform the Federal Government of the kinds of service which it desires most and if granted proper authority, the Government can establish regulations which will provide in a given community for the operation of a limited number of broadcasting stations. These stations may, for example, operate simultaneously on different wave lengths and each furnish to the public a different type of service. This would make it possible for the individual desiring to receive a certain broadcast service to push a button on his receiving set which is marked for that service. The final tuning of his set to the station which transmits this class of broadcasting can be done by a single lever or control knob. The principle of a receiving set which might be developed to fit such a condition is shown in Fig. 2. A large number of problems, both

technical and administrative, must be solved in order to make such service really satisfactory.

Uses of Radio.—It is not necessary to look to the future for extensive use of radio. It is used more extensively than most people realize for navigational aids, for communication with ships, aircraft, remote regions,

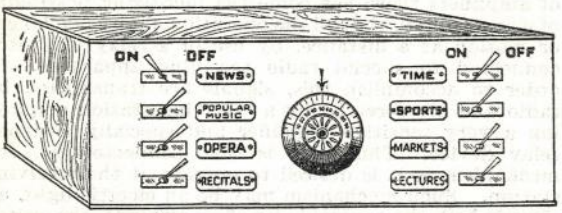


Fig. 2—Radio Broadcast Receiving Set of the Near Future.

and across the oceans. Its use on trains and all vehicles will come. Forests will be better protected by its use for instant reporting of fires. The broadcasting of news and important announcements will be accomplished and regulated with a perfection that would now seem startling. The problem in radio, will, indeed, be to restrict its uses enough to permit any messages getting through. The very need of control of the air will be a powerful factor for world organization and peace.

By inserting in this binder the additional sheets to be published from time to time—as fast as improvements in radio are perfected—the holder will be kept fully advised of all advances of moment in the art of radio communication and will thus be enabled to maintain his equipment at maximum efficiency.

RADIOTRON UV-199

RADIOTRON UV-199, the latest addition to the Radiotron family, is the smallest tube in the line. Its overall height is 3½" and diameter is 1". The filament current consumption per tube amounts to only .06 ampere. Three ordinary number 6 dry cells connected in series are all that is required to energize the filament.

UV-199 is not only an exceptional detector and audio-frequency amplifier but has proved to be an excellent radio-frequency amplifier, the capacity between elements being lower than that of any previous Radiotron because the plate and grid leads, and pins, are diagonally opposite instead of adjacent.



Radiotron UV-199
Price $6.50

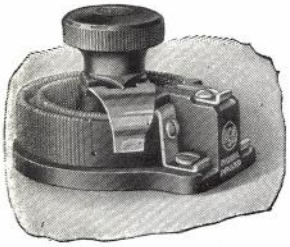
ELECTRICAL CHARACTERISTICS

Filament Battery Source	4.5	Volts
Filament Terminal Voltage	3.0	Volts
Filament Current	0.06	Amp.
Plate Voltage		
Detector	40	Volts
Amplifier	(See below)	

40 Volts with 0.5 to 1.0 negative grid bias
60 " " 1.0 " 3.0 " " "
80 " " 3.0 " 4.5 " " "

RADIO CORPORATION OF AMERICA

Rheostat PR-539



A new rheostat to handle from one to six Radiotron UV-199 tubes. There are two windings; both connected in series offer 33 ohms resistance for one tube—the outer one, 18 ohms for two tubes—the inner one, 15 ohms for three tubes—both in parallel, 8.2 ohms for four to six tubes.

RHEOSTAT PR-539..... $3.00

Socket UR-590

Socket UR-590 has been developed specially for Radiotron UV-199. The G and P connecting screws, like the corresponding pins in UV-199, are opposite instead of adjacent, making the wiring of multi-tube sets much easier, and the spring contacts are of new type, giving consistently sure, positive contact.



SOCKET UR-590..... $.75

Adapter UR-589



This adapter permits Radiotron UV-199 to be inserted in the standard navy type socket such as RCA Model UR-542, and takes care of the difference in the contact arrangement and the sizes of the new and old tubes. A wide, knurled ring makes it easy to grasp, insert and remove.

ADAPTER UR-589..... $1.00

RADIO CORPORATION OF AMERICA

KENNEDY

The Royalty of *Radio*

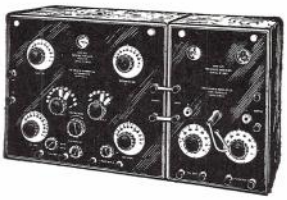
KENNEDY Regenerative Radio Receivers are more than mere receiving sets. Each is a beautifully finished example of handicraft that warrants it being placed in the finest homes, yet the prices are less than you would expect to pay for such scientific and artistic masterpieces.



Type-281
The "Broadcast"

The "Broadcast" Receiver, with a wave-length range of 175 to 900 meters, is specially designed for present-day broadcasting. It is extremely selective, permitting to an unusual degree the elimination of interference. Cabinet is of solid mahogany, with brilliantly polished Formica panel. Its black dials are graduated in white etching. Metal parts are heavily nickel-plated.

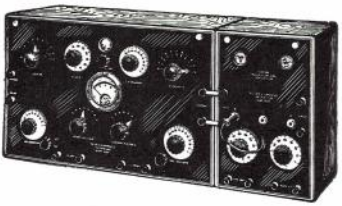
Price, Type-281 Receiver and two-stage Audio Amplifier.....$145.00
Type-281 Receiver only..... 90.00



Type-220
The "Intermediate"

This set operates with high efficiency over a wave-length range of 200 to 3,200 meters, bringing in many commercial as well as all broadcasting stations. The cabinet is of beautifully grained solid walnut; satin-finished dials inset in panel tend to outwardly reflect the character of the instrument.

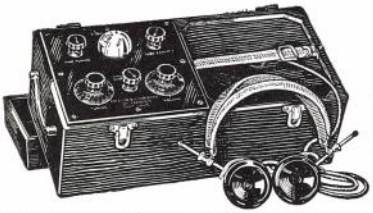
Price, Type-220 Receiver and two-stage Audio Amplifier.....$235.00
Type-220 Receiver only..... 150.00



Type-110
The "Universal"

For those desiring the finest radio receiving set obtainable—professional men, scientists, technical men, clubs, hotels, colleges, etc. —the Kennedy Universal stands supreme. It will detect, regenerate or oscillate over the entire wave-length range of 200 to 25,000 meters. It covers the entire field of radio.

Price, Type-110 Receiver and two-stage Audio Amplifier.....$370.00
Type-110 Receiver only..... 285.00



Type-311
The "Portable"

This is a handy, compact set (only 15x7½x7 inches), so easily transported that you can take it with you wherever you go—yet so beautifully finished that you will be proud to have it in your home. Highly selective, yet easily operated. It is designed for the new standard tubes, including the 1½-volt dry-cell type. When dry-cell type is used, the set is entirely self-contained, space being provided in the sturdy, beautiful oak cabinet for both "A" and "B" batteries and phones. Wave-length range, 175 to 700 meters.

Price, Type-311 Receiver, complete, with dry-cell tube, dry batteries, phones.....$75.00

Write for Descriptive Circulars

Descriptive circulars on any or all of these sets will gladly be sent on request.

Arrange for Demonstration

Any Kennedy dealer will gladly arrange to demonstrate any of these sets. If there is no Kennedy dealer near you, write to us direct for information.

All Kennedy Receiving Sets are regenerative—licensed under Armstrong U. S. Pat. No. 1,113,149.

The Colin B. Kennedy Company

Saint Louis **San Francisco**

DUBILIER SPECIALTIES
For Better Reception



The Dubilier Variadon with back-of-panel mounting. In this case the dial is not supplied as a part of the Variadon. The amateur can use his own dial.

The DUBILIER VARIADON

The Dubilier Variadon is a fool-proof mica variable condenser, which is no thicker than an ordinary dial but which does the work of the usual multi-plate variable air-condenser. It tunes over a scale of 340 degrees. Hence the rate of capacity increase is so low, as the knob is turned degree by degree, that a vernier is practically unnecessary. The Variadon is unaffected by body capacity effects. There are no sliding contacts. Permanent connections are made to the condenser plates. The Variadon cannot be short-circuited by shocks or falls; its adjustment is permanent. It can be mounted on the front or rear of panel. The following retail prices do not include dial for back of panel mounting.



The Dubilier Variadon as it is supplied from the factory with graduated dial and knob.

Capacities	*Retail Prices*
.0004 mfd	$2.50
.0006 mfd	2.50
.001 mfd	3.50

Dubilier Micadons

Dubilier Micadons are small pressed mica condensers which are permanent in capacity. They are widely used in receiving sets to reduce tube howling and hence to improve the quality of broadcast reception.



Micadon type 600 is made in capacities .0001, .00025, and .0005 mfd. Price 75 cents each. In capacities .001 to .005 mfd., 75 cents to $1.00 each. .006 mfd., $1.25.

Micadon type 601 is a small pressed mica condenser not much larger than a postage stamp. It is provided with eyelet terminals. Micadon type 601 may be connected in parallel by bolts or in series with machine screws. Price 35 to 75 cents each, depending on capacity (.0001 to .006 mfd.).



Micadon type 601 can be mounted on binding posts with special adjustable clips (ten cents extra) or provided with grid-leak clips (ten cents extra) or furnished with extended tabs 2¼" over all (ten cents extra).

Micadon type 610 is made in capacities .001 to .02 mfd., 75 cents to $1.50 each. This type has the same general characteristics as type 600, but is slightly larger.

The Dubilier Ducon Taps Lamp Sockets For Radio Concerts



The Dubilier Ducon is the standard socket plug of the world. Four hundred thousand are in use in the United States, Canada and Europe. It completely does away with the antenna. Any set can be connected with a lamp socket by means of the Ducon. Not only is the cumbrous antenna dispensed with, but the tuning is sharper than with an antenna so that simple sets become more selective. Approved by the Laboratories of the National Board of Fire Underwriters. Sold on five days' trial. Money refunded at place of purchase if not satisfactory. Price $1.50.

The Du-tec—A Synthetic Crystal



The Du-tec is a synthetic chemical rectifier which takes the place of natural crystals. Every point of the Du-tec is sensitive. Hence tedious and frequent adjustment of the "cat-whisker" is obviated. The Du-tec does not oxidize or age from exposure and does not deteriorate with high temperature. Mounted in cup ready for use. Price 30 cents each.

BRANCH OFFICES

Los Angeles, Cal. 329 Union League Building
St. Louis, Mo. Syndicate Trust Building
Washington, D. C. Munsey Building
Chicago, Ill. 33 S. Clinton Street
Atlanta, Ga. 302 Flatiron Building
Pittsburgh, Pa. 705 Granite Building
Huntington, W. Va. 1028 Fourth Ave.

DUBILIER Condenser & Radio Corp.
48-50 West 4th St. N.Y.

Distributed in Canada by Canadian General Electric Co. Ltd., Toronto, Canada.

England: The Dubilier Condenser Co., Ltd., London
Germany: Telefunken Company, Berlin
France: C. Capart, Paris

The New Grebe Broadcast Receiver

Type CR-12

HERE is a Receiver which embodies, for the first time, the principles of Regeneration and Tuned Radio-Frequency Amplification.

You may now receive all broadcasting without outdoor antenna, loop or storage battery! A silk-covered wire but twenty feet long, supplied with this Receiver, does the work of the unsightly outdoor antenna or loop. This wire may be concealed behind the picture moulding or run along the baseboard.



Four tubes, of any type now on the market, are used. In fact, you may use a different kind of tube in each socket, and in no case do you require more than one A battery. Thus, you may use a 5-volt tube in the radio-frequency circuit, a 1½-volt tube as a detector, a 3-volt tube in the first stage and a 5-volt tube in the second stage of audio-frequency amplification.

The Receiver has only two extremely simple tuning adjustments. The secondary Tuning Dial is graduated in wave-lengths, enabling you to locate quickly a given station.

Its wave-length range—200 to 600 meters—receives all broadcasting.

You may set this receiver up immediately anywhere and anyone may, in a moment, master its simple adjustments.

The complete Receiver is contained in a beautiful walnut cabinet, attractively finished, with compartments for all necessary batteries.

There is no unsightly wiring of any kind.

The New Grebe Broadcast Receiver

Type CR-12

No Other Receiver has these

Seven Points of Satisfaction

1. Requires no outdoor antenna—no loop.
2. Uses all kinds of tubes (4 of them) in any desired combination.
3. Employs the perfect combination of Regeneration and Tuned Radio-Frequency Amplification with only two tuning adjustments.
4. Receives all broadcasting.
5. Tuning Dial graduated in wave-lengths.
6. May be set up immediately, and successfully operated—anywhere—by anyone.
7. Complete, self-contained Receiver, in attractively finished walnut cabinet, with compartments for A and B batteries.

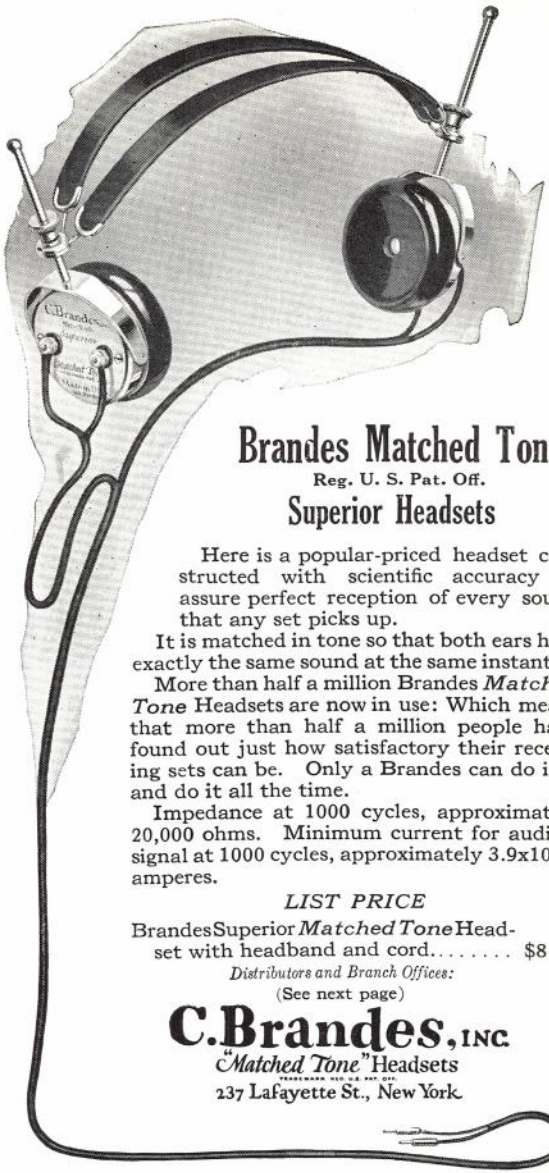
Licensed under
Armstrong U. S. Pat.
No. 1,113,149

Ask Your Dealer
or
Write for Leaflet

A. H. GREBE & CO., INC.

Richmond Hill, N. Y.

Western Branch: 451 East 3rd St., Los Angeles, Cal.



Brandes Matched Tone

Reg. U. S. Pat. Off.

Superior Headsets

Here is a popular-priced headset constructed with scientific accuracy to assure perfect reception of every sound that any set picks up.

It is matched in tone so that both ears hear exactly the same sound at the same instant.

More than half a million Brandes *Matched Tone* Headsets are now in use: Which means that more than half a million people have found out just how satisfactory their receiving sets can be. Only a Brandes can do it—and do it all the time.

Impedance at 1000 cycles, approximately 20,000 ohms. Minimum current for audible signal at 1000 cycles, approximately 3.9x10.10 amperes.

LIST PRICE

Brandes Superior *Matched Tone* Headset with headband and cord..... $8.00

Distributors and Branch Offices:

(See next page)

C. Brandes, INC.

"Matched Tone" Headsets

TRADE-MARK REG. U.S. PAT. OFF.

237 Lafayette St., New York



Brandes Matched Tone

Reg. U. S. Pat. Off.

NAVY TYPE HEADSETS

The Navy Type Brandes *Matched Tone* Headset represents the crowning achievement of fifteen years of successful radio experience. It is the standard of perfection in radio headsets.

Its extreme lightness, its radio-frequency shielded headset cord, and its unequalled clarity and harmony of tone make it the ideal headset for home use or most exacting laboratory work.

Impedance at 1000 cycles, approximately 25,000 ohms. Minimum current for audible signal at 1000 cycles, approximately 1.6x10 amperes.

LIST PRICE

Brandes Navy Type *Matched Tone* Headset with headband and radio-frequency cord.....$12.00

Distributors and Branch Offices:

76 Pearl Street, Boston, Mass.
Munsey Building, Washington, D. C.
331 Rialto Building, San Francisco, Cal.
302 Flatiron Building, Atlanta, Ga.
33 South Clinton Street, Chicago, Ill.
705 Granite Building, Pittsburgh, Pa.
1028 Fourth Avenue, Huntington, West Va.

Distributed in Canada by Perkins Electric, Limited
Toronto MONTREAL Winnipeg

Made in Canada and England by
Canadian Brandes, Limited, Toronto and London

Distributors in Australia and New Zealand
International Electric Co., Wellington, N. Z.

C. Brandes, INC.

"*Matched Tone*" Headsets

TRADE MARK REG. U.S. PAT. OFF.

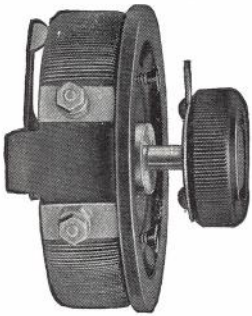
237 Lafayette St., New York.

INSTRUMENTS USED BY
The Bureau of Standards and Other Leading Laboratories

For nearly a decade the General Radio Company has been manufacturing radio measuring instruments and standard radio parts that are used extensively in the radio laboratories of the Bureau of Standards. Signal Corps, Navy and other government departments, as well as in such nationally known laboratories as those of the General Electric Co., Westinghouse Electric & Mfg. Co., Western Electric Co., Radio Corp. of America and many others. Our measuring instruments, in particular, are used extensively in the laboratories of the country's leading educational institutions such as Harvard, Yale, Massachusetts Institute of Technology, Princeton and over one hundred other colleges.

Our instruments fall into two main groups; namely, measuring instruments, and standard radio parts. Because of the research work required for the development of the measuring instruments, we have much data that has been used in the development of our standard parts, which has made them far superior to the usual parts on the market. It is not possible to list all of these parts here and it is, accordingly, recommended that you send for FREE RADIO BULLETIN 914LA.





These parts which have become known as a standard of quality include the following:

Filament Rheostats
High Resistance Potentiometers
Vacuum Tube Sockets
Amplifying Transformers
Modulation Transformers
Inductance Coils
Hot-Wire Ammeters
Low Loss Condensers
Wavemeters
Porcelain Insulators
Switches and Sinclair Small Parts

GENERAL RADIO COMPANY

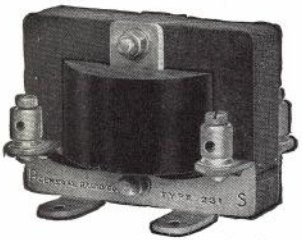
Manufacturers of

Electrical and Radio Laboratory Apparatus

MASSACHUSETTS AVE. and WINDSOR ST.

CAMBRIDGE 39 **MASSACHUSETTS**

GENERAL RADIO
AMPLIFYING TRANSFORMER



The GENERAL RADIO COMPANY was the first company to have available for the experimenter a closed core audio-frequency amplifying transformer. This was before the United States entered the war. Many of these transformers were supplied to the army and navy during the war, and with the return of amateur radio after the war, thousands have been supplied for use in this country and abroad.

The subject of amplification has received much attention in our research laboratory. Improvements have been made from time to time until now our present model, the Type 231A, represents the best in amplifying transformer design.

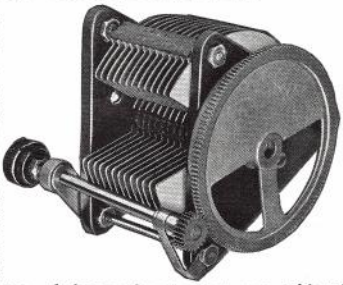
The Type 231A Amplifying Transformer is designed to give the maximum of amplification possible without distortion. It is the result of careful engineering design.

The electrical constants of the windings are as follows:

	Primary	Secondary
Direct current resistance, ohms.....	1,100	5,500
A.C. resistance at 1000 cycles, ohms...	11,000	130,000
Reactance at 1000 cycles, ohms.....	66,000	700,000

Price, Completely Mounted, $5.00

GENERAL RADIO
LOW LOSS CONDENSER



The careful design of the Type 247 Condenser provides not only for low dielectric losses, but for a rigid mechanical assembly with a special type of spring bearing which supplies the correct amount of friction, compensates for wear, and assures positive electrical contact with the moving plates. All the thrust is on the upper bearing, which is so arranged that there can be no change of capacity, nor short-circuiting, if the distance between bearings becomes changed. The plates, of heavy brass sheet, are soldered together and to the shaft and supports, thus increasing the rigidity and lowering plate resistance.

The zero capacity is low, 25 MMF. mounted, and 15 MMF. unmounted, making a wide range of wavelengths possible.

Type 247E 500 MMF. Mounted. Without gear	$5.50
Type 247F 500 MMF. Unmounted. Without gear.....	3.25
Type 247G 500 MMF. Mounted. With gear.....	7.25
Type 247H 500 MMF. Unmounted. With gear.....	5.00
Knob, dial and indicator button for use with unmounted condenser.....	.50
Gear, pinion, pinion shaft and mounting supports, per set.....	1.75

GENERAL RADIO COMPANY

Cambridge 39 **Massachusetts**

RESONANCE IN RADIO

How Resonance Affects Your Broadcast Reception

Resonance is the free passage of energy at one or several frequencies and the suppression of energy at other frequencies.

Radio Broadcasting consists of a few radio frequencies and many audio frequencies.

Resonance at radio frequencies produces large antenna currents, sharp tuning, selectivity and radio-frequency amplification.

Resonance at audio frequencies produces distortion and howling.

Acme Parts are designed and constructed by Transformer, Telephone and Radio Engineers and Manufacturers for maximum amplification without distortion.

Acme Apparatus Co. Cambridge, Mass.
186 Massachusetts Ave.

Transformer and Radio Engineers and Manufacturers

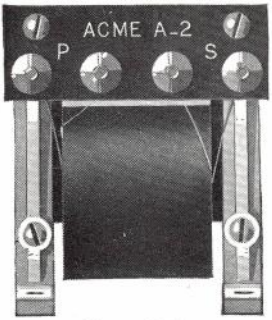
New York Chicago
Cleveland Kansas City
San Francisco

Send 10 cents for Booklet AA on Amplification without Distortion.

ACME

for amplification

ACME AUDIO-FREQUENCY AMPLIFYING TRANSFORMER



Type A-2

The universal transformer for operation on all types of vacuum tubes up to three stages.

Audio-Frequency for Volume

ACME RADIO-FREQUENCY AMPLIFYING TRANSFORMER



Type R-2

Type R-3 for second stage, Type R-4 for third stage. For amateur wave lengths, R-1, R-2, R-4.

Radio-Frequency for Distance

Acme Transformers cover the new wave length band.

Inquire About the New **Acme Kleerspeaker**

Send 10 cents for Booklet A A on Amplification without Distortion.

ACME

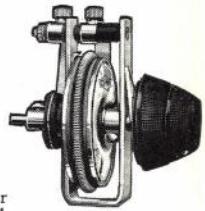
for amplification

C-H Radio Rheostats Built By Rheostat Builders

C-H 4 Ohm Vernier Rheostat

Perfect control for standard 6-volt detector tubes and dry cell (WD11) tubes. Built and guaranteed by the master builder of all rheostatic-control apparatus. Arranged for panel mounting and finished in satin nickel and ebony black. Packed complete with template.

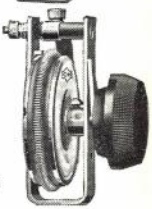
Type 11601—H1.....$1.50

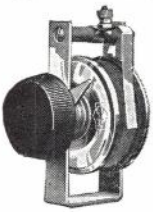


C-H 4 Ohm Radio Rheostat

Furnished without vernier adjustment—for amplifier control (using C-301 type, 5-volt. 1 amp., or WD11, dry-cell tubes). Large number of small turns of resistor gives accurate control, the nickeled pointer at all times indicating amount of resistance in circuit. Packed complete in unit box with template.

Type 11601—H2.....$1.00



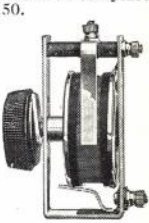


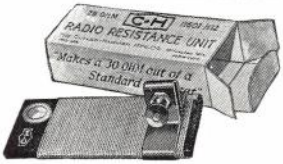
C-H 30 Ohm Radio Rheostat

For the control of amplifier tubes of the C-301-A type in which a current of only approximately ¼ amp. is required. Pointer indicating, and furnished (like all other C-H rheostats) with comfortable cone-shaped knobs of genuine Thermoplax. Packed complete with template for easy panel mounting, $1.50.

C-H Radio "A" Battery Potentiometer

For the accurate control of the plate potential for increased range and signal strength. Resistor cannot become displaced through constant usage and is subjected to minimum wear. Matches exactly in appearance and correctness of construction this precision line of radio control instruments *"built by current control specialists."*.....$1.50





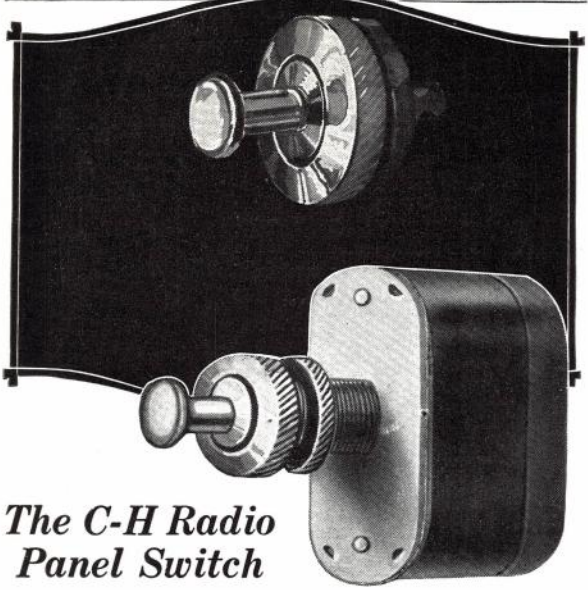
C-H Radio Resistance Unit

The C-H Radio Resistance Unit adds to your present rheostats just the number of ohms required for the regulation of the new ¼ ampere tubes. It can be attached to any rheostat already mounted, or directly on the panel.....$.25

Over a Quarter Million C-H Rheostats Now in Use

CUTLER-HAMMER

CUTLER-HAMMER



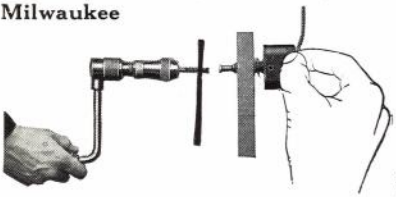
The C-H Radio Panel Switch

A rugged, positive battery switch that will add greatly to the convenience of your set. Protects your tubes and storage cell—or it can control your "B" battery. Makes it possible to interrupt reception temporarily without disturbing the adjustment of your various control instruments. Has a score of possible uses on every panel. Easily and quickly installed—only a single $\frac{3}{8}$" hole required. Set rings allow for mounting on panels of any thickness. Convenient screw posts with cupped washers provide for easy wiring. Push and pull mechanism operates positive knife blade wipe contact—a perfect switch guaranteed by the famous C-H trademark.

THE CUTLER-HAMMER MFG. CO.

Member, Radio Section, Associated Manufacturers of Electrical Supplies

Milwaukee **Wisconsin**



1. Drill only one $\frac{3}{8}$" hole through your panel.

2. Adjust set rings to thickness of panel and insert switch in hole.

3. Turn knurled mounting ring home, and switch is installed—no screws—no measurements.

Here's a present for you!

Free Book of Hook-Ups



Contains over 25 tested circuits. Valuable information on the subject of amplification.

Explains and defines the use of Radio and Audio Frequency Transformers.

Tells how to get the best results.

Send two-cent stamp for postage.

RAULAND MFG. CO.
200 No. Jefferson St., Chicago, Ill.

Manufacturers of

"ALL-AMERICAN"
Transformers

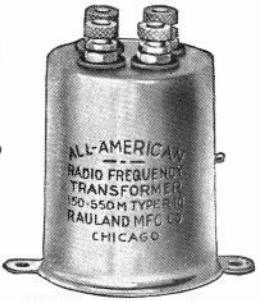
RADIO and AUDIO Frequency

Confidence

These leading manufacturers of quality radio sets:

Cutting & Washington
Jones Radio
Cleartone
Zenith (Chicago Radio Laboratory)
Midwest Radio Co.
Audiola Radio Co.
Illinois Radio Eng. Co.

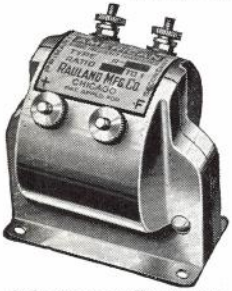
and others — use



Radio Frequency Transformer
R-10 (150-550 meters) $4.50

"ALL-AMERICAN" Amplifying Transformers

(Radio and Audio Frequency)



Audio Frequency Transformer
R-12 (Ratio 3 to 1) $4.50
R-21 (Ratio 5 to 1) 4.75
R-13 (Ratio 10 to 1) 4.75

as standard equipment in their sets. This is reason enough why any man building his own set should use "All-American" Transformers. The sales of these manufacturers depend on the efficiency of their apparatus. The confidence they place in "All-American" Transformers to function properly under all conditions is proof of the quality of these instruments. Buy them—use them—and you, too, will endorse them. Every live radio dealer carries them. To help you get the best results from your radio set we offer **FREE** a book of twenty-five tested hook-ups. Send 2c stamp for postage.

RAULAND MFG. CO.

200 No. Jefferson St., Chicago, Ill.

Proved Perfect for Panelling!

For absolute insulation, professional smartness and highest efficiency, there is nothing to equal it for radio panelling.

bakelite dilecto!!

(Laminated Phenolic Condensation Material)

Beautiful, sleek-black surface. Supremely hard and tough.

Tests highest in dielectric strength, tensility and volume resistivity. LOWEST in dielectric losses.

For over nine years used and approved by the United States Navy and Signal Corps.

Proof against heat, water, steam, fumes, milder acids and corrosives. Cannot swell, warp or crack. Machines readily.

Electrical supply men can get Bakelite-Dilecto (XX grade) cut to any requirement.

Complete data, specifications and prices on request.

The **Continental Fibre Company**
Newark, Delaware

Bakelite-Dilecto!!

"Laminated Phenolic Condensation Material"

For Radio Panels and Other Insulation

Available in sheets, rods, tubes and special shapes. Grade XX Black is always used for radio work.

Bakelite-Dilecto XX has the lowest moisture absorption of all fibrous base insulating materials. Containing the least moisture, it has the lowest power loss.

Bakelite-Dilecto will not warp, swell nor shrink. It retains its finish even if used out of doors. Has much greater dielectric and mechanical strength and resistance to heat than is required in radio.

It has a coefficient of expansion of only .000014 per degree Fahrenheit, a specific gravity of 1.32 to 1.38, is waterproof and permanent and will withstand a temperature of 220 degrees Fahrenheit continuously without injury.

It is chemically inert, insoluble and infusible. Salt water and gasoline will not injure it. Nor is it affected by weak acids or alkalies, ordinary solvents such as alcohol, benzol, turpentine, acetone and hot water.

Bakelite-Dilecto has a tensile strength of 12,000 pounds per square inch and modulus of elasticity of 1,500,000.

It has a dielectric strength far above any normal need. 100,000 volts will not puncture a sheet only 3–16 inches thick!

Any other information gladly supplied anyone on request.

The Continental Fibre Company

Newark, Delaware

Dealer Service from:

New York City,
233 Broadway

Chicago,
332 S. Michigan Ave.

Pittsburgh,
301 5th Avenue

San Francisco,
75 Fremont Street

Los Angeles,
411 S. Main Street

Seattle,
95 Connecticut Street

DALTON WHITTIER TRUE CO.
ESTRU
MANFRS. CHICAGO.

UNI-FLEX PARTS

Flexible Units

Compact—Efficient
Interchangeable
Inductance Units

Combinations made up for use in all standard circuits.

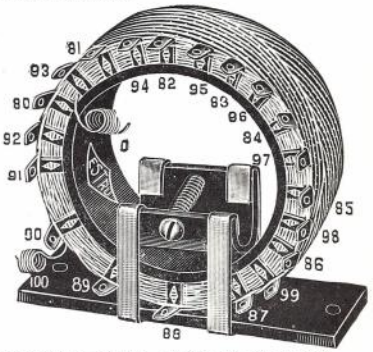
In the present state of the art it is impossible to construct coils having pure inductance values, due to the capacity or condenser effect between the turns of the wire which make up the inductances. This capacity depends upon the closeness of the turns and the characteristics of the dielectric or insulating material between conductors. All of these factors have been carefully considered, both in the design and manufacture of ESTRU Lattice Wound Products.

Estru Lattice Coils

Uni-Flex 100-T-22
For Use as Active Twenty in Kauffman Circuit
Unmounted . . . $2.25
With Uni-Flex Mounting . . . 3.00

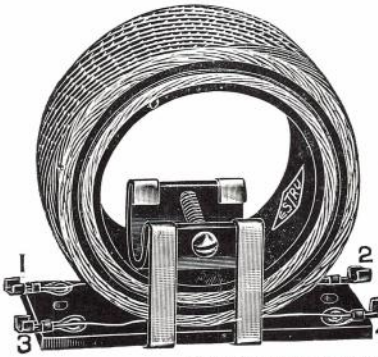
Uni-Flex 150-T-10
For Ultra Audion
Unmounted . . . $2.00
With Uni-Flex Mounting . . . 2.75

Uni-Flex Coil Mount
Fits any Size Coil
Plain $.85
With Solder Clips 1.10
With Nickel Plated Binding Posts 1.50



Inductances in All Standard Sizes—Plain or Mounted.

EFFICIENT DESIGN
SAVING OF SPACE
TESTED PRODUCTS
RESULTS THAT COUNT
UNI-FLEX PARTS



Uni-Flex R. F. Transformer
Turn Ratio
4 to 1 $2.00
For use in Neutrodyne Circuit.

Use with Estru Micro-Mike Condenser $.75
Variable Capacity
.7 to 2.0 M.M.F.

Uni-Flex Load Coil $2.00
Natural Wave-Length 50 to 100 or 150 Meters.

Estru Radio Products

At your Dealer or Write Us



ESTRU
Lattice Variometer

7 P-Plate Type $5.00
7 G-Grid Type 5.00
360 Degree Vernier Type (in Process)

ESTRU Lattice Vario-coupler (Sec. Cut). $4.50

Uni-Flex Coupler

Interchangeable and Build-Up Rotors and Stators—Makes Any Combination of Coupling—Transformer or Fixed or Variable Inductance. Single Unit.....$4.50



Similar to rotor end of cut but uses double-end tube with rotor in center: mounts Lattice Coil Stator above or below rotor. Two or more Rotor Tubes may be fitted together with Lattice Coil Stators.

ESTRU RADIO RECEIVING SETS

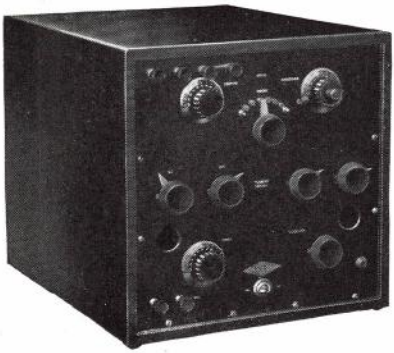
Compact—Portable—Efficient

A-R-1 "The Reflex" Baby (1-Tube)
R-1 "The Wanderer" (1-Tube)
A-R-5 "The Neutro-Flex" (5-Tube)
Built for the "Auto" or "Camp"

ESTRU "BABY GRAND" RECEIVER

(4-tube)

1 Radio Frequency—Detector—2 Audio Frequency
1 Loud Speaking Horn—1 Set (90 Volts) "B" Battery



Front has Gold Finished Patented Composition Horn

Mahogany Cabinet

Cut shows Rear Operating End

Complete Operating Unit and Panel Slides out of Cabinet

ALL-IN-ONE CUBIC FOOT

DALTON, WHITTIER, TRUE COMPANY

2905 W. Madison St. **Chicago, Illinois**

Designing Engineers and Manufacturers

Magnavox Products

THE MAGNAVOX line includes an ideal apparatus for every purpose of Radio reproduction and amplification. Where Radio equipment must meet the test of satisfying really discriminating people, Magnavox is certain to be installed.

MAGNAVOX RADIO

The Reproducer Supreme

Magnavox Reproducers are constructed on the famous Electro-Dynamic principle—the only principle by which a reproducer can meet the requirements of sound amplification according to its original pitch, quality and volume.

These instruments can be used with any receiving set of good quality: without the Magnavox no Radio set is complete.

R2 Magnavox Reproducer with 18-inch curvex horn: the utmost in amplifying power; for clubs, hotels, dance halls, large audiences, etc. Requires only .6 of an ampere for the field.....$60.00

R3 Magnavox Reproducer with 14-inch curvex horn in efficient acoustic finish (as illustrated): ideal for use in homes, offices, amateur stations, etc., ...$35.00

The horn supplied with Magnavox Reproducers is of spun copper, resisting accidental blows and deterioration through climatic changes.



R 3
with 14-inch horn

Magnavox Power Amplifiers

THESE are true *Power* Amplifiers, designed to give a *Power* output, and are free from elements of distortion. Any standard amplifying tube may be used.

Magnavox Power Amplifiers (in two sizes as listed below) are made to the highest standards of technical efficiency, convenience of operation and refinement of finish.



Model C 2-stage

AC-2-C with two stages of power amplification. For use with the Magnavox Reproducer, to insure getting largest possible power input. Switching from stage to stage is made easy by master switches. Bakelite panel. Highly finished hardwood case. Without tubes.....$55.00

AC-3-C: the same as the above instrument, but with three stages of power amplification, giving maximum volume. Without tubes.....$75.00

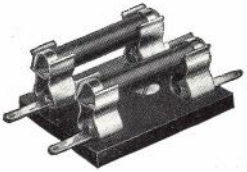
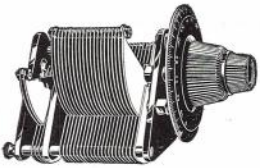
Magnavox Products can be had of good dealers everywhere. Ask for demonstration.

THE MAGNAVOX COMPANY
OAKLAND, CALIFORNIA
New York Office, 370 Seventh Ave.

KELLOGG SWITCHBOARD & SUPPLY COMPANY

Chicago, Illinois

SYMBOLS OF STANDARD EQUIPMENT

Symbol	Illustration	Description
 **Fixed Condenser**		Size 1 7/8" x 3/4". Capacities—.01—.006 .005—.0025—.001 —.0005—.00025 Mfd.
 Grid Condenser		Miniature condensers have the same capacities as the above fixed condensers.
 **Variable Condenser**		Decremeter Type 11-23 and 43 plate types with or without vernier. Standard capacities.
 **Variometer**		All Bakelite moulded variometer. Two rotor and three stator terminals. Standard wound. For panel or base mounting.
 **Phone**		2400 ohm per pair. Impedance and ampere turns at highest relative efficiency. Super sensitive. Lightest in weight; first to receive signals, last to choke on amplification.

Symbol	Illustration	Description
Jack		All combinations. Positive contacts. Constant spring tension. Insulated frame.
Plug.		Fit all standard jacks. Handsomely finished.
Resistance		Inductive or non-inductive. All resistances. Also open core chokes.
Inductance with Iron Core		Standard "chokes" for all circuits and values.
Transmitter		Standard Microphone. Super sensitive. The results of 25 years experience.
		3″ and 4″ all Bakelite. Non-warping reinforced construction. The better dial that you have been waiting for.
		All Bakelite tube socket. Takes all standard tubes. "The Standard Socket."

With Kellogg  Use is the Test

If your dealer or jobber does not handle Kellogg equipment, write us for catalog, advising us of his name. Address Department E.

KELLOGG SWITCHBOARD & SUPPLY COMPANY

Chicago, Illinois

RADION

The Supreme Insulation for Radio Panels and Parts

AMERICAN HARD RUBBER CO.

11 Mercer Street, New York City

The four most important characteristics of insulating material for radio use are *low phase angle difference, low dielectric constant, high resistivity and non-absorbent qualities.*

RADION excels in all the above. Comparisons with Phenolic and Laminated Phenolic Insulations are as follows:

	RADION	*Phenolic* and *Laminated Phenolic Materials*
Phase Angle Difference ...	0.5 to 0.6	2.0 to 3.7
Dielectric Constant.....	3.9	5.8 to 7.4
Resistivity (Megohms-cm).	1.0×10^8	1.4×10^4 to 2.2×10^6
Absorption of Moisture:		
In Air.....	0.005 to 0.02%	0.28% to 0.49%
In Water.....	0.08% to 0.11%	1.42% to 7.81%

Figures given in the above table for phase angle difference, dielectric constant and resistivity were reported by the Bureau of Standards. Absorption of moisture in air and in water were determined in our own laboratory.

These results prove that RADION surpasses all other materials in electrical insulating properties.

RADION is a special compound of hard rubber developed particularly for radio use and manufactured exclusively by the American Hard Rubber Company. It is non-porous, non-absorbent, warp resisting, absolutely permanent, may be easily moulded or accurately machined to gauge, drilled, cut, threaded, engraved, stamped, sanded and polished without danger of chipping.

RADION PANEL SHEETS

Radion panel sheets are made in two colors:—black and mahogany grained (called mahoganite). This latter material is the handsomest panel stock ever offered for radio use. The beautiful mahogany grain is obtained by a new special process. This material will enhance the appearance of any outfit, as it not only possesses the grained effect of genuine mahogany, but has a fine, satin-like surface polish, unusual among insulation materials.

Stock Sizes—Black and Mahoganite

Thickness	Size	Thickness	Size	Thickness	Size
3/16 ins.	6x 7 ins.	3/16 "	7x14 ins.	1/4 "	10x12 ins.
3/16 "	6x10½ "	3/16 "	7x18 "	5/16 "	12x14 "
3/16 "	6x14 "	3/16 "	7x21 "	5/16 "	12x21 "
5/16 "	6x21 "	5/16 "	7x24 "	5/16 "	14x18 "
5/16 "	7x 9 "	5/16 "	7x48 "	5/16 "	20x24 "
5/16 "	7x10 "	5/16 "	9x14 "	1/4 "	20x24 "
5/16 "	7x12 "	5/16 "	10x12 "		

Special Sizes—Special sizes are supplied in lots aggregating 50 or more square feet per size.

RADION PARTS

Variometer Rotors—No. .012B, supplied unwired and without metal parts as shown in figure, 2½″ wide by 3 11/16″ in diameter.

Quotations on special moulded Variometer parts on request.









Dial **V-T Socket** **Insulator**

Radion Dials—Moulded in one piece with tapered knobs, graduated either clockwise or counter-clockwise. Made in standard sizes of 2¼, 3, 3¼ and 4 inches in diameter with metal insert and adapter bushing to fit either 3/16 or ¼ inch shafts. Packed in individual boxes.

V-T Sockets—A Moulded Radion socket and base for standard detector and amplifier tubes. Supplied complete with metal contact pieces and binding posts. Packed in individual boxes.

Aerial Insulators, No. 1 Brown, 3½ in. overall—Unusually high dielectric strength and strain resistance. Galvanized eyelets are strongly imbedded.

Standard Rods and Tubing—A large range of sizes of unpolished rods and tubing are carried in stock in standard 24″ lengths; prices on application.

Variometer Tubing—Supplied unpolished as shown



No.	Outside Diam.	Wall Thickness	Length
1	4″	1/8″	3″
2	4″	1/8″	3½″
3	4″	1/8″	4″
4	4″	1/8″	5″
5	2″	1/8″	30″
6	2½″	1/8″	30″
7	3″	1/8″	30″
8	3½″	1/8″	30″
9	4″	1/8″	30″



6233

Radion Knobs—Knobs No. 6233 are regularly supplied with set screws and drilled to fit shafts as ordered.

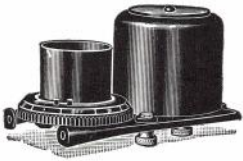
RADION Panels and parts are stocked by dealers in radio and electrical supplies.

AMERICAN HARD RUBBER CO.
11 Mercer St., New York City

EISEMANN



Detector Unit



Amplifier Unit

The outstanding feature of Eisemann Radio Units, aside from their uniform excellence, is ease of assembly.

The panels, illustrated on the following page, are completely drilled and the Units are fastened with screws and nuts. The only tool required is a small screw-driver.

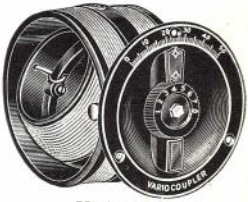


Condenser



Variometer

Complete descriptive catalog mailed free upon request



Variocoupler

METAL PANELS

Aluminum panels in several sizes are offered for use with Eisemann Radio Units.

Uniform size openings permit interchangeable mounting.

The metal panel, itself, acts as an ideal capacity shield; its use being made possible by the complete self-insulation of all Eisemann Units.



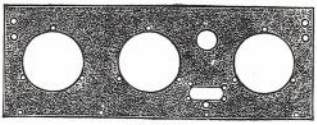
Type A-2



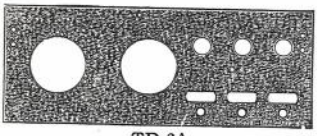
T-1



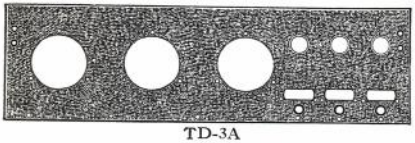
TD-2



TD-3



TD-2A



TD-3A

For sale by progressive dealers everywhere

EISEMANN MAGNETO CORPORATION

William N. Shaw, President

Brooklyn, N. Y.

Detroit **Chicago** **San Francisco**

CONDENSITE CELORON

STANDARD RADIO PANEL

The Easy-to-Merchandise Radio Panel

Celoron Radio Panels, ready-cut in standard sizes, eliminate the delay and inconvenience of cutting from sheet stock. They come in widely varying sizes, ranging from small panels suitable for sets just big enough to hold a crystal detector and tuning coil to man-size sets employing three stages of amplification.

You will find Celoron Panels easy to stock and easy to sell. They give you a handy packaged article that moves quickly from your shelves and has a good margin of profit. You sell a radio panel that never fails to give satisfaction. Celoron ready-cut panels are designed to meet practically every need of the set-builder.

Each panel is neatly trimmed and wrapped separately, with complete instructions for working and finishing printed on the envelope. You hand your customer the size he wants, ring up the sale, and the transaction is completed. Radio fans, eager to build their sets, appreciate this quick service. It usually encourages them to buy more of their radio equipment from you.

Diamond State Fibre Company
Bridgeport (near Philadelphia), Penna.

CONDENSITE CELORON

STANDARD RADIO PANEL

Celoron Panels have fine insulating qualities and high dielectric strength. They are approved by leading radio experts, the Navy Department Bureau of Engineering, and the U. S. Signal Corps.

The radio set-builder likes Celoron Panels because they are easy to work, machine, drill, and tap, and will engrave evenly without feathering.

You can obtain Celoron Panels ready-cut in the following standard sizes:

1—6 x 7 x 1/8	5— 9 x 14 x 3/16
2—7 x 9 x 1/8	6— 7 x 21 x 3/16
3—7 x 12 x 1/8	7—12 x 14 x 3/16
4—7 x 18 x 3/16	*8— 7 x 46 x 3/16

**This strip for cutting special sizes. Celoron is made also in full-size sheets, from which we will cut any size desired.*

With Celoron Ready-Cut Panels on your shelves you save the time, money, and energy lost by cutting from sheet stock.

When you order, indicate by number the panel sizes you want and enclose your jobber's name and address.

Diamond State Fibre Company
Bridgeport (near Philadelphia), Penna.

Branch Factory and Warehouses
Boston, Chicago, San Francisco

In Canada
Diamond State Fibre Company of Canada, Limited.
245 Carlaw Avenue, Toronto

CHAPTER EIGHT

UNDERWRITERS' REGULATIONS

March 12, 1923

Note:—These rules do not apply to Radio Equipment installed on shipboard.

In setting up Radio Equipment all Wiring Pertaining thereto must conform to the General Requirements of the National Electrical Code for the class of work installed and the following Additional Specifications:

FOR RECEIVING STATIONS ONLY

(Sections a to d, inclusive, do not apply when antenna is installed inside of buildings.)

ANTENNA:

a. Antenna and counterpoise outside of buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be located and provided with suitable clearances, so as to prevent accidental contact with such wires by sagging or swinging.

Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

Light and power circuits, if used for receiving antenna, need not conform to any of the above requirements, but the devices used to connect the light and power conductors to radio receiving sets must be of an approved type.

LEAD-IN-CONDUCTORS:

b. Lead-in-conductors shall be of copper, approved copper-clad steel or other metal which will not corrode excessively, and in no case shall they be smaller than No. 14 B. & S. gauge except that bronze or copper-clad steel not less than No. 17 B. & S. gauge may be used.

Lead-in-conductor on the outside of buildings shall not come nearer than four (4) inches to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor that will maintain permanent separation. The non-conductor shall be in addition to any insulation on the wire.

Lead-in-conductor shall enter building through a non-combustible, non-absorptive insulating bushing slanting upward toward the inside.

PROTECTIVE DEVICE:

c. Each lead-in conductor shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of five hundred (500) volts or less, properly connected and located either inside the building at some point between the entrance and the set which is convenient to a ground (see section d), or outside the building as near as practicable to the point of entrance. **The protector shall not be placed in the immediate vicinity of easily ignitable stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.**

The use of an antenna grounding switch is desirable, but does not obviate the necessity for the approved protective device required under this section. The antenna grounding switch if installed shall, in its closed position, form a shunt around the protective device.

A knife switch not less than 30 amp., 250 volts, is recommended to be located between lead-in conductor and receiving set.

Fuses are not required, but if used shall not be placed in the circuit from the antenna through the protective device to ground.

PROTECTIVE GROUNDING CONDUCTOR:

d. The protective grounding conductor may be bare and shall be of copper, bronze or approved copper-clad steel. The grounding conductor shall not be smaller than the lead-in conductor, and in no case shall be smaller than No. 14 B. & S. gauge if of copper, nor smaller than No. 17 B. & S. gauge if of bronze or copper-clad steel. The grounding conductor shall be run in as straight a line as possible from the protective device to a good, permanent ground. **Preference shall be given to water piping.** Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounds such as driven pipes, rods, plates, cones, etc. **Gas piping shall not be used for the ground.**

The grounding conductor shall be protected where exposed to mechanical injury. An approved ground clamp shall be used where the grounding conductor is connected to pipes or piping.

RECEIVING EQUIPMENT GROUNDING CONDUCTOR:

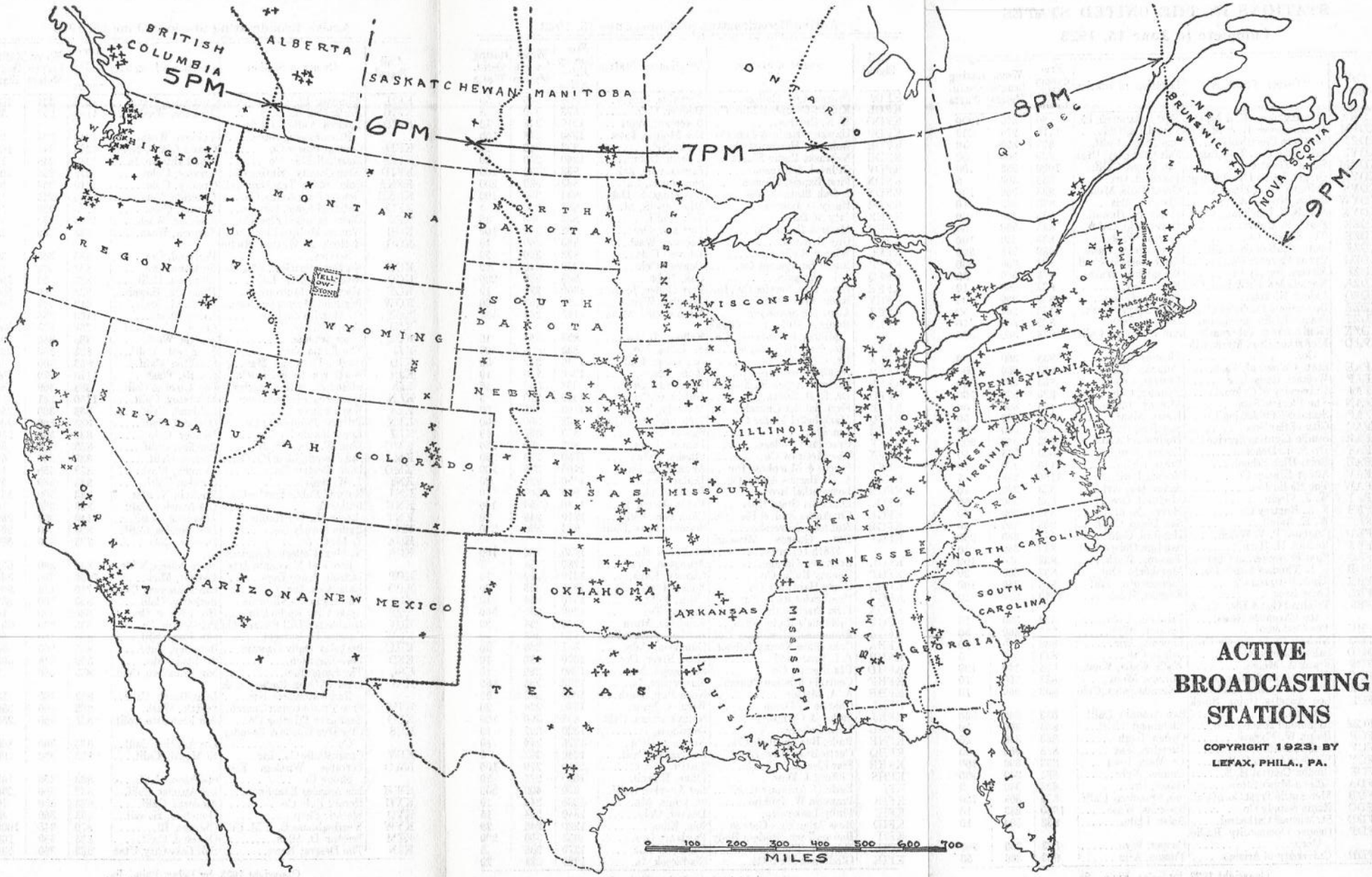
e. The grounding conductor may be run either inside or outside of the building. The protective grounding conductor and ground installed as specified in Section d may be used as the operating ground. In this case the operating grounding conductor should preferably be connected to the ground terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, the grounding conductor being bare or with an insulating covering.

WIRES INSIDE BUILDINGS:

f. Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than two (2) inches to any electric light or power wire not in conduit, unless separated therefrom by some continuous and firmly fixed non-conductor making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire. Porcelain tubing or approved flexible tubing may be used for encasing wires to comply with this rule.

Storage battery leads shall consist of conductors having approved rubber insulation. It is recommended that the circuit from the storage battery be properly protected by fuses located as near as possible to the battery.



ACTIVE BROADCASTING STATIONS

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LIST OF RADIO TELEPHONE BROADCASTING STATIONS IN THE UNITED STATES

Complete to June 15, 1923

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KDKA	Westinghouse. E. & M. Co.	East Pittsburgh, Pa.	920	326	1000
KDPM	Westinghouse E. & M. Co.	Cleveland, Ohio....	1110	270	250
KDPT	Southern Electrical Co.....	San Diego, Calif....	833	360	50
KDYL	Salt Lake Eve. Telegram..	Salt Lake City, Utah	833	360	50
KDYM	Savoy Theatre.....	San Diego, Calif....	1090	252	100
KDYQ	Oregon Inst. of Technology	Portland, Ore.....	833	360	5
KDYS	Tribune Publishing Co....	Great Falls, Mont..	833	360	100
KDYW	Smith, Hughes & Co.....	Phoenix, Ariz.....	833	360	10
KDYX	Star Bull. Publishing Co...	Honolulu, Hawaii...	833	360	100
KDZB	Frank E. Siefert.....	Bakersfield, Calif...	833	360	100
KDZE	The Rhodes Co.....	Seattle, Wash.....	833	360	100
KDZF	Auto. Club of So. Calif....	Los Angeles, Calif..	1080	278	500
KDZG	Cyrus Pierce & Co.....	San Francisco, Calif.	833	360	500
KDZI	Electric Supply Co.....	Wenatchee, Wash...	833	360	50
KDZK	Nevada Mach'y & Elec. Co.	Reno, Nev.....	833	360	10
KDZQ	Pyle & Nichols.....	Denver, Colo.....	833	360	100
KDZR	Bellingham Publishing Co..	Bellingham, Wash..	1150	261	50
KDZT	Seattle Radio Association..	Seattle, Wash.....	833	360	10
KDZX	Glad Tidings Tabernacle..	San Francisco, Calif.	833	360	500
KFAD	McArthur Bros. Mercantile Co.....	Phoenix, Ariz.....	833	360	150
KFAE	State College of Wash.....	Pullman, Wash.....	833	360	500
KFAF	Western Radio Corp.....	Denver, Colo.....	833	360	550
KFAJ	University of Colorado....	Boulder, Colo.....	833	360	100
KFAN	The Electric Shop.....	Moscow, Idaho.....	833	360	50
KFAP	Standard Publishing Co...	Butte, Mont.....	833	360	50
KFAQ	City of San Jose.....	San Jose, Calif.....	833	360	500
KFAR	Studio Lighting Service Co.	Hollywood, Calif...	833	360	200
KFAT	Dr. S. T. Donohue.....	Eugene, Ore.....	1090	275	50
KFAU	Boise High School.....	Boise, Idaho.....	1110	270	10
KFAV	Abbot-Kinney Co.....	Venice, Calif.....	1160	258	5
KFAW	The Radio Den.....	Santa Ana, Calif...	833	360	10
KFAY	W. J. Virgin.....	Medford, Ore.....	833	360	50
KFBB	F. A. Buttrey Co.....	Havre, Mont.....	833	360	50
KFBC	W. K. Azbill.....	San Diego, Calif....	833	360	20
KFBD	Clarence P. V. Welch.....	Hanford, Calif.....	833	360	250
KFBE	Reuben H. Horn.....	San Luis Obispo, Cal.	833	360	10
KFBG	First Presbyterian Church.	Tacoma, Wash.....	833	360	100
KFBH	L. L. Thomas Music Co...	Marshfield, Ore....	833	360	20
KFBK	Kimball-Upson Co.....	Sacramento, Calif..	833	360	100
KFBL	Leese Bros.....	Everett, Wash.....	1340	224	10
KFBS	Trinidad Gas & Elec. Co. & the Chronicle News.....	Trinidad, Colo.....	833	360	15
KFBU	The Cathedral.....	Laramie, Wyo.....	833	360	50
KFCB	Nielson Radio Supply Co..	Phoenix, Ariz.....	833	360	10
KFCD	Salem Electric Co.....	Salem, Ore.....	833	360	5
KFCF	Frank A. Moore.....	Walla Walla, Wash.	833	360	100
KFCH	Elec. Service Station, Inc..	Billings, Mont.....	833	360	10
KFCK	Colorado Springs Radio Co.	Colorado Sprgs.,Colo	833	360	10
KFCL	Los Angeles Union Stock Yards.....	San Antonio, Calif..	833	360	500
KFCM	Richmond Radio Shop....	Richmond, Calif....	833	360	50
KFCP	Ralph W. Flygare.....	Ogden, Utah.....	833	360	25
KFCV	Fred Mahaffey, Jr.....	Houston, Tex.....	833	360	50
KFCY	Western Union College....	Le Mars, Iowa.....	833	360	100
KFCZ	Omaha Central H. S.....	Omaha, Nebr.....	833	360	300
KFDA	Adler's Music Store.....	Baker, Ore.....	833	360	5
KFDB	Mercantile Trust Co. of Cal.	San Francisco, Calif.	590	509	750
KFDC	Radio Supply Co.....	Spokane, Wash.....	1060	283	10
KFDD	St. Michael Cathedral.....	Boise, Idaho.....	833	360	10
KFDF	Casper Community Radio Corp.....	Casper, Wyo.....	833	360	200
KFDH	University of Arizona.....	Tucson, Ariz.....	833	360	50

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Active Broadcasting Stations, June 15, 1923

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFDJ	Oregon Agri. College.....	Corvallis, Ore.....	833	360	50
KFDL	Knight-Campbell Mus. Co.	Denver, Colo.....	833	360	5
KFDO	H. E. Cutting.....	Bozeman, Mont....	1210	248	10
KFDP	Hawkeye Radio & Sup. Co.	Des Moines, Iowa..	1080	278	100
KFDR	Bullock's Hardware Co....	York, Nebr.....	833	360	10
KFDU	Nebraska Radio Elec. Co..	Lincoln, Nebr.....	1250	240	20
KFDV	Gilbrech & Stinson.....	Fayetteville, Ark...	833	360	100
KFDX	First Baptist Church.....	Shreveport, La.....	833	360	200
KFDY	S. Dak. State College.....	Brookings, S. Dak..	833	360	100
KFDZ	Harry O. Iverson.....	Minneapolis, Minn..	833	360	5
KFEB	City of Taft.....	Taft, Calif.....	833	360	50
KFEC	Meier & Frank Co.....	Portland, Ore.....	833	360	100
KFEJ	Guy Greason.....	Tacoma, Wash.....	833	360	10
KFEL	Winner Radio Corp.....	Denver, Colo.....	833	360	50
KFEP	Radio Equipment Co.....	Denver, Colo.....	1250	240	10
KFEQ	J. L. Scroggin.....	Oak, Nebr.....	833	360	200
KFER	Auto. Elec. Service Co., Inc.	Fort Dodge, Iowa..	1300	231	10
KFEV	Radio Elec. Shop.....	Douglas, Wyo.....	1140	263	100
KFEX	Augsburg Seminary.....	Minneapolis, Minn.	1150	261	100
KFEY	Bunker Hill & Sullivan Mining & Concentr. Co.	Kellogg, Idaho.....	833	360	10
KFEZ	Am. Soc. Mech. Engrs.....	St. Louis, Mo.....	833	360	500
KFFA	Dr. R. O. Shelton.....	San Diego, Calif....	1240	242	50
KFFB	Jenkins Furniture Co.....	Boise, Idaho.....	1250	240	10
KFFE	Eastern Oregon Radio Co..	Pendleton, Ore.....	833	360	10
KFFO	Dr. E. H. Smith.....	Hillsboro, Ore.....	1310	229	5
KFFP	First Baptist Church.....	Moberly, Mo.....	1190	275	50
KFFQ	Marksheffel Motor Co....	Colo. Springs, Colo..	833	360	100
KFFR	Jim Kirk.....	Sparks, Nev.....	833	360	10
KFFV	Graceland College.....	Lamoni, Iowa.....	833	360	250
KFFX	The McGraw Co.....	Omaha, Nebr.....	1080	278	250
KFFY	Pincus & Murphey, Inc...	Alexandria, La.....	1100	275	100
KFFZ	A. G. Barnes Amus. Co...	Dallas, Tex.....	1330	226	20
KFGB	Loewenthal Bros.....	Pueblo, Colo.....	833	360	10
KFGC	Louisiana State Univ.....	Baton Rouge, La...	1180	254	100
KFGD	Chickasha Rad. & Elec. Co.	Chickasha, Okla....	1210	248	20
KFGH	Stanford University.....	Stanford Univ., Calif.	833	360	250
KFGJ	Nat. Guards Missouri, 138th Infantry.....	St. Louis, Mo.....	1130	266	100
KFGL	Arlington Garage.....	Arlington, Ore.....	1280	234	5
KFGP	Cheney Radio Co.....	Cheney, Kans.....	1310	229	10
KFGQ	Crary Hardware Co.....	Boone, Iowa.....	1330	226	20
KFGV	Heidbreder Radio Sup. Co.	Utica, Nebr.....	1340	224	10
KFGX	First Presbyterian Church.	Orange, Tex.....	1200	250	500
KFGY	Gjelhaug's Radio Shop....	Baudette, Minn....	1340	224	20
KFGZ	Emmanuel Missionary Col.	Berrien Sprgs., Mich.	1120	268	10
KFHA	Colo. State Normal School.	Gunnison, Colo.....	833	360	50
KFHB	P. L. Boardwell.....	Hood River, Ore....	1070	280	10
KFHD	Utz Electric Co.....	St. Joseph, Mo.....	1330	226	10
KFHF	Central Christian Church..	Shreveport, La.....	1130	266	150
KFHH	A. A. McCue.....	Neah Bay, Wash...	1060	283	50
KFHI	Charles V. Dixon.....	Wichita, Kans.....	1340	224	20
KFHJ	Fallon & Company.....	Santa Barbara, Calif.	833	360	100
KFHL	Penn College.....	Oskaloosa, Ia.....	1320	227	10
KFHP	Radio Bug Products Co....	Kearney, Nebr. ...	1220	246	10
KFHQ	Curtis Bros. Hdw. Store...	Los Gatos, Calif....	1240	242	5
KFHR	Star Elec. & Radio Co.....	Seattle, Wash.....	1110	270	100
KFHS	Clifford J. Dow.....	Lihue, Hawaii.....	1090	275	30
KFI	Earle C. Anthony (Inc.)...	Los Angeles, Calif..	640	469	500
KFIB	Franklin W. Jenkins.....	St. Louis, Mo.....	1230	244	10
KFIC	Philip Laskowitz.....	Denver, Colo.....	1340	224	15
KFID	Ross Arbuckle's Garage...	Iola, Kans.....	1220	246	20
KFIF	Benson Tech. Student Body	Portland, Ore.....	833	360	200
KFIJ	Sidney I. Thorean.....	Platte, S. Dak.....	1270	236	5
KFIK	Gladbrook Elec. Co.....	Gladbrook, Ia.....	1280	234	20

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Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KFIL	Windisch El. Farm Eq. Co.	Louisburg, Kans....	1280	234	100
KFIO	North Central H. S.....	Spokane, Wash.....	1190	252	50
KFIQ	Yakima Valley Radio Broadcasting Assoc....	Yakima, Wash.....	1240	224	50
KFJA	Central Power Co.....	Grand Island, Nebr.	1230	244	100
KFJB	Marshall Elec. Co.....	Marshalltown, Ia...	1210	248	10
KFJD	Weld County Printing Co..	Greeley, Colo.....	1270	236	100
KFKA	Colo. State Teachers Col.	Greeley, Colo.....	1210	248	50
KFKH	Denver Park Amus. Co....	Lakeside, Colo.....	1330	226	10
KFLE	National Educ. Service....	Denver, Colo.....	1120	268	10
KFZ	Doerr-Mitchell Elec. Co...	Spokane, Wash.....	1060	283	5
KGB	Wm. A. Mullins Elec. Co...	Tacoma, Wash.....	833	360	10
KGG	Hallock & Watson Radio Service.....	Portland, Ore.....	833	360	50
KGN	Northwestern Rad. Mfg.Co.	Portland, Ore.....	833	360	15
KGO	Altadena Radio Lab.....	Altadena, Calif.....	833	360	500
KGU	Marion A. Mulrony.....	Honolulu, Hawaii...	833	360	500
KGW	Portland Morn'g Oregonian	Portland, Ore.....	610	492	500
KGY	St. Martins College.....	Lacey Wash.....	1160	258	5
KHJ	Times-Mirror Co.....	Los Angeles, Calif..	760	395	500
KHQ	Louis Wasmer.....	Seattle, Wash.....	833	360	200
KJJ	The Radio Shop.....	Sunnyvale, Calif....	833	360	200
KJQ	Gould, The Light Man....	Stockton, Calif.....	833	360	5
KJR	Northwest Radio Ser. Co...	Seattle, Wash.....	1110	270	100
KJS	Bible Inst. of Los Angeles..	Los Angeles, Calif..	833	360	750
KLN	Monterey Electric Shop...	Monterey, Calif....	1150	261	10
KLS	Warner Bros.....	Oakland, Calif.....	833	360	250
KLX	Tribune Publishing Co....	Oakland, Calif.....	833	360	100
KLZ	Reynolds Radio Co.....	Denver, Colo.....	833	360	250
KMC	Wm. W. Lindsay, Jr.....	Reedley, Calif.....	833	360	50
KMJ	San Joaquin Lt. & P'r. Corp.	Fresno, Calif.....	833	360	50
KMO	Love Electric Co.....	Tacoma, Wash.....	833	360	10
KNI	T. W. Smith.....	Eureka, Calif.....	833	360	50
KNJ	Roswell Public Service Co..	Roswell, N. Mex...	833	360	150
KNN	Bullock's.....	Los Angeles, Calif..	833	360	10
KNT	Gray's Harbor Radio Co..	Aberdeen, Wash....	1140	263	250
KNV	Radio Supply Co.....	Los Angeles, Calif..	833	360	200
KOA	Y. M. C. A.....	Denver, Colo.....	833	360	500
KOB	N. Mex. College of Agriculture and Mechanic Arts.	State College,N.Mex.	833	360	500
KOP	Detroit Police Dept.....	Detroit, Mich.....	1050	286	500
KPO	Hale Bros, Inc.....	San Francisco, Cal..	710	423	500
KQI	University of California....	Berkeley, Calif.....	833	360	250
KQP	Apple City Radio Club....	Hood River Ore....	833	360	10
KQV	Doubleday-Hill Electric Co	Pittsburgh, Pa.....	833	360	250
KQW	Charles D. Herrold.....	San Jose, Calif.....	833	360	50
KRE	Berkeley Daily Gazette....	Berkeley, Calif.....	833	360	50
KSD	Post-Dispatch.....	St. Louis, Mo.....	550	546	500
KSL	The Emporium.....	San Francisco, Calif.	833	360	5
KSS	Prest & Dean Radio Co. & Radio Research Soc.....	Long Beach, Calif..	833	360	10
KTW	First Presbyterian Church.	Seattle, Wash.....	833	360	250
KUO	Examiner Printing Co.....	San Francisco, Calif.	833	360	250
KUS	City Dye Works & Laundry Co.....	Los Angeles, Calif..	833	360	100
KUY	Coast Radio Co., Inc.....	El Monte, Calif....	833	360	100
KWG	Portable Wireless Telephone Co.....	Stockton, Calif.....	833	360	100
KWH	Los Angeles Examiner.....	Los Angeles, Calif...	833	360	250
KXD	Herald Pub. Co.....	Modesto, Calif.....	833	350	10
KYQ	Electric Shop.....	Honolulu, Hawaii...	833	360	40
KYW	Westinghouse E. & M. Co.	Chicago, Ill.....	870	345	1000
KZM	Preston D. Allen.....	Oakland, Calif.....	833	360	100
KZN	The Deseret News.....	Salt Lake City, Utah	833	360	500

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Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
KZV	Wenatchee Battery & Motor Co.	Wenatchee, Wash.	833	360	50
WAAB	Valdemar Jensen	New Orleans, La.	1120	268	100
WAAC	Tulane University	New Orleans, La.	833	360	400
WAAD	Ohio Mechanics Institute	Cincinnati, Ohio.	833	360	25
WAAF	Chicago Daily Drovers Journal	Chicago, Ill.	1050	286	200
WAAH	Commonwealth Elec. Co.	St. Paul, Minn.	833	360	250
WAAK	Gimbel Bros.	Milwaukee, Wis.	1070	280	100
WAAL	Beamish Electric Co.	Minneapolis, Minn.	833	360	300
WAAM	I. R. Nelson Co.	Newark, N. J.	1140	263	250
WAAN	University of Missouri	Columbia, Mo.	1180	254	50
WAAP	United Electric Co.	Wichita, Kans.	833	360	500
WAAW	Omaha Grain Exchange	Omaha, Nebr.	833	360	150
WAAY	Yahrling-Raynor Piano Co.	Youngstown, Ohio.	833	360	150
WAAZ	Hollister-Miller Motor Co.	Emporia, Kans.	833	360	100
WABA	Lake Forest College	Lake Forest, Ill.	1130	266	100
WABB	Dr. John B. Lawrence	Harrisburg Pa.	1130	266	10
WABC	Fulwider-Grimes Bat. Co.	Anderson, Ind.	1310	229	10
WABD	Parker High School	Dayton, Ohio.	1060	283	10
WABE	Y. M. C. A.	Washington, D. C.	1060	283	50
WABF	Mt. Vernon Register-News Co.	Mt. Vernon, Ill.	1280	234	250
WABG	Arnold Edwards Piano Co.	Jacksonville, Fla.	1210	248	10
WABH	Lake Shore Tire Co.	Sandusky, Ohio.	1250	240	100
WABI	Bangor Ry. & Elec. Co.	Bangor, Me.	1250	240	50
WABJ	Radio Laboratories	South Bend, Ind.	1250	240	10
WABK	First Baptist Church	Worcester, Mass.	1190	252	10
WABL	Connecticut Agri. College	Storrs, Conn.	1060	283	100
WABM	F. E. Doherty	Saginaw, Mich.	1180	254	100
WABN	Waldo C. Grover	La Crosse, Wis.	1280	234	100
WABO	Lake Ave. Baptist Church	Rochester, N. Y.	1190	252	30
WBAA	Purdue University	West Lafayette, Ind.	833	360	250
WBAD	Sterling Electric Co.	Minneapolis, Minn.	833	360	100
WBAF	Fred M. Middleton	Moorestown, N. J.	833	360	100
WBAH	The Dayton Co.	Minneapolis, Minn.	833	360	500
WBAK	Penn. State Dept. of Police	Harrisburg, Pa.	833	360	500
WBAN	Wireless Phone Corp.	Paterson, N. J.	1230	244	100
WBAO	James Millikin University	Decatur, Ill.	833	360	50
WBAP	Wortham-Carter Pub. Co.	Fort Worth, Tex.	630	476	500
WBAU	Republican Publishing Co.	Hamilton, Ohio.	1160	258	50
WBAV	Erner & Hopkins Co.	Columbus, Ohio.	770	390	500
WBAW	Marietta College	Marietta, Ohio.	1220	246	100
WBAX	John H. Stenger, Jr.	Wilkes-Barre, Pa.	833	360	20
WBAY	Western Elec. Co.	New York City.	610	492	500
WBBA	Newark Radio Lab.	Newark, Ohio.	1250	240	20
WBBC	Sterling Radio Equip. Co.	Sterling, Ill.	1310	229	50
WBBD	Barbey Battery Service	Reading, Pa.	1280	224	50
WBL	T. & H. Radio Co.	Anthony, Kans.	1150	261	100
WBS	D. W. May (Inc.)	Newark, N. J.	833	360	10
WBT	Southern Radio Corp.	Charlotte, N. C.	833	360	500
WBU	City of Chicago	Chicago, Ill.	1050	286	500
WBZ	Westinghouse E. & M. Co.	Springfield, Mass.	890	337	750
WCAB	Newburgh News Printing & Pub. Co.	Newburgh, N. Y.	833	360	15
WCAC	John Fink Jewelry Co.	Fort Smith, Ark.	833	360	20
WCAD	St Lawrence University	Canton, N. Y.	1070	280	50
WCAE	Kauffman & Baer Co.	Pittsburgh, Pa.	650	461	500
WCAG	Clyde R. Randall	New Orleans, La.	1120	268	50
WCAH	Entrekin Electric Co.	Columbus, Ohio.	1050	286	100
WCAJ	Nebraska Wesleyan Univ.	Univ. Place, Nebr.	833	360	15
WCAK	Alfred P. Daniel	Houston, Texas.	833	360	10
WCAL	St. Olaf College	Northfield, Minn.	833	360	250
WCAM	Villanova College	Villanova, Pa.	833	360	100
WCAO	Sanders & Stayman Co.	Baltimore, Md.	833	360	50

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Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WCAR	Alamo Radio Elec. Co., Inc.	San Antonio, Tex.	833	360	100
WCAS	Dunwoody Industr. Inst.	Minneapolis, Minn.	833	360	100
WCAT	S. Dak. State Sch. of Mines	Rapid City, S. Dak.	1250	240	100
WCAU	Durham & Co.	Philadelphia, Pa.	1050	286	500
WCAV	J. C. Dice Electric Co.	Little Rock, Ark.	833	360	50
WCAW	Quincy Electric Supply Co.	Quincy, Ill.	833	360	10
WCAX	University of Vermont	Burlington, Vt.	833	360	300
WCAY	Kesselman O'Driscoll Music House	Milwaukee, Wis.	1150	261	500
WCAZ	Robert E. Compton and Carthage College	Carthage, Ill.	833	360	300
WCBA	Chas. W. Haimbach	Allentown, Pa.	1070	280	5
WCBB	K. & K. Radio Supply Co.	Greenville, Ohio	1250	240	100
WCBD	Wilbur Glenn Voliva	Zion City, Ill.	870	345	500
WCE	Findley Electric Co.	Minneapolis, Minn.	833	360	50
WCK	Stix, Baer & Fuller	St. Louis, Mo.	833	360	100
WCM	University of Texas	Austin, Tex.	833	360	500
WCN	Clark University	Worcester, Mass.	833	360	250
WCX	Detroit Free Press	Detroit, Mich.	580	517	500
WDAD	Cent. Kans. Rad. Sup. Co.	Lindsborg, Kans.	833	360	10
WDAE	Tampa Daily Times	Tampa, Fla.	833	360	500
WDAF	The Kansas City Star	Kansas City, Mo.	730	411	500
WDAG	J. L. Martin	Amarillo, Tex.	1140	263	100
WDAH	Trinity Methodist Church	El Paso, Tex.	833	360	200
WDAI	Hughes Radio Corp.	Syracuse, N. Y.	1220	246	100
WDAJ	Atlanta & West Pt.R.R. Co.	College Park, Ga.	833	360	500
WDAK	Hartford Courant	Hartford, Conn.	1150	261	100
WDAL	Florida Times-Union	Jacksonville, Fla.	833	360	200
WDAO	Automotive Electric Co.	Dallas, Tex.	833	360	50
WDAP	Board of Trade	Chicago, Ill.	833	360	250
WDAR	Lit Brothers	Philadelphia, Pa.	760	395	500
WDAS	Samuel A. Waite	Worcester, Mass.	833	360	10
WDAU	Slocum & Kilburn	New Bedford, Mass.	833	360	50
WDAX	First National Bank	Centerville, Iowa	833	360	100
WDAY	Fargo Radio Service Co.	Fargo, N. Dak.	1230	244	50
WDBC	Kirk Johnson & Co., Inc.	Lancaster, Pa.	1160	258	50
WDBF	Robert G. Phillips	Youngstown, Ohio	1150	261	50
WDM	Church of the Covenant	Washington, D. C.	833	360	50
WDT	Ship Owners Radio Service	New York City	740	405	500
WDZ	James L. Bush	Tuscola, Ill.	1080	278	10
WEAA	Fallain & Lathrop	Flint, Mich.	1070	280	150
WEAB	Standard Radio Equip. Co.	Fort Dodge, Iowa	833	360	250
WEAD	Henry Radio & El. Sup.Co.	Atwood, Kans.	1120	268	100
WEAF	American Tel. & Tel. Co.	New York City	610	492	500
WEAG	Nichols-Hineline-Bassett Lab.	Edgewood, R. I.	1300	231	10
WEAH	Lander Radio Co.	Wichita, Kans.	833	360	500
WEAI	Cornell University	Ithaca, N. Y.	1050	286	500
WEAJ	Univ. of South Dakota	Vermillion, S. Dak.	833	360	200
WEAK	Julius B. Abercrombie	St. Joseph, Mo.	833	360	10
WEAM	Borough of No. Plainfield	N. Plainfield, N. J.	1190	252	50
WEAN	The Shepard Company	Providence, R. I.	1100	273	100
WEAO	Ohio State University	Columbus, Ohio	833	360	500
WEAP	Mobile Radio Co., Inc.	Mobile, Ala.	833	360	50
WEAR	Frank A. Munsey Co.	Baltimore, Md.	833	360	50
WEAS	The Hecht Co.	Washington, D. C.	833	360	250
WEAU	Davidson Bros. Co.	Sioux City, Iowa	833	360	100
WEAV	Sheridan Elec. Service Co.	Rushville, Nebr.	833	360	100
WEAX	T. J. M. Daly	Little Rock, Ark.	833	360	20
WEAY	Iris Theater	Houston, Tex.	833	360	250
WEB	Benwood Co., Inc.	St. Louis, Mo.	833	360	500
WEH	Midland Refining Co.	Tulsa, Okla.	833	360	500
WEV	Hurlburt-Still Electrical Co	Houston, Tex.	833	360	50
WEW	St. Louis University	St. Louis, Mo.	1150	261	100
WEY	Cosradio Co.	Wichita, Kans.	833	360	500

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Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WFAA	A. H. Belo & Co., Publishers	Dallas, Texas	630	476	500
WFAB	Carl F. Woese	Syracuse, N. Y.	1280	234	250
WFAC	Superior Radio Co.	Superior, Wis.	833	360	100
WFAF	H. C. Spratley Co.	Poughkeepsie, N. Y.	833	360	10
WFAG	Radio Engineering Lab.	Waterford, N. Y.	833	360	500
WFAH	Electric Supply Co.	Port Arthur, Tex.	833	360	10
WFAJ	Hi-Grade Wireless Instrument Co.	Asheville, N. C.	833	360	50
WFAM	Times Publishing Co.	St. Cloud, Minn.	833	360	20
WFAN	Hutchinson Elec. Serv. Co.	Hutchinson, Minn.	833	360	100
WFAQ	Missouri Wesleyan College and Cameron Radio Co.	Cameron, Mo.	833	360	10
WFAT	Daily Argus-Leader	Sioux Falls, S. Dak.	833	360	100
WFAV	University of Nebraska	Lincoln, Nebr.	833	360	100
WFAW	Miami Daily Metropolis	Miami, Fla.	833	360	200
WFAZ	So. Carolina Radio Shop	Charleston, S. C.	833	360	100
WFI	Strawbridge & Clothier	Philadelphia, Pa.	760	395	500
WGAL	Lancaster Electric Supply & Constr. Co.	Lancaster, Pa.	1210	248	10
WGAM	Orangeburg Rad. Equip. Co	Orangeburg, S. C.	833	360	20
WGAN	Cecil E. Lloyd	Pensacola, Fla.	833	360	15
WGAQ	Glenwood Radio Corp.	Shreveport, La.	833	360	50
WGAR	Southwest American	Fort Smith, Ark.	833	360	20
WGAU	Radio Mfg. & Serv. Co.	Wooster, Ohio	1330	226	20
WGAW	Ernest C. Albright	Altoona, Pa.	1150	261	100
WGAX	Radio Elec. Co.	Washington Court House, Ohio.	833	360	20
WGAY	Northwestern Radio Co.	Madison, Wis.	833	360	100
WGAZ	South Bend Tribune	South Bend, Ind.	833	360	50
WGF	Register & Tribune	Des Moines, Iowa	833	360	100
WGI	Am. Rad. & Research Corp.	Medford Hillside, Mass.	833	360	500
WGL	Thos. F. J. Howlett	Philadelphia, Pa.	833	360	500
WGM	Atlanta Constitution	Atlanta, Ga.	700	429	500
WGR	Federal Tel. & Tel. Co.	Buffalo, N. Y.	833	360	250
WGV	Interstate Elec. Co.	New Orleans, La.	833	360	100
WGY	General Electric Co.	Schenectady, N. Y.	790	380	1000
WHA.	University of Wisconsin	Madison, Wis.	833	360	500
WHAA	State Univ. of Iowa	Iowa City, Iowa	1060	283	100
WHAB	The Clark W. Thompson Co.	Galveston, Tex.	833	360	100
WHAC	Cole Bros. Elec. Co.	Waterloo, Iowa	833	360	10
WHAD	Marquette University	Milwaukee, Wis.	833	360	100
WHAE	Automotive Elec. Serv. Co.	Sioux City, Iowa	833	360	20
WHAG	Univ. of Cincinnati	Cincinnati, Ohio	1350	222	100
WHAH	Hafer Supply Co.	Joplin, Mo.	833	360	250
WHAI	Radio Equip. & Mfg. Co.	Davenport, Iowa	833	360	50
WHAK	Roberts Hardware Co.	Clarksburg, W. Va.	833	360	15
WHAL	Lansing Capital News	Lansing, Mich.	1210	248	20
WHAM	Univ. of Rochester	Rochester, N. Y.	833	360	100
WHAO	F. A. Hill	Savannah, Ga.	833	360	100
WHAP	Otta & Kuhns	Decatur, Ill.	833	360	10
WHAQ	Semmes Motor Co.	Washington, D. C.	1240	242	10
WHAS	Courier-Journal & Louisville Times	Louisville, Ky.	750	400	500
WHAV	Wilmington Elec. Spec. Co.	Wilmington, Del.	833	360	100
WHAW	Pierce Elec. Co.	Tampa, Fla.	833	360	10
WHAY	Huntington Pub. Co.	Huntington, Ind.	833	360	10
WHAZ	Rensselaer Polytechnic Inst.	Troy, N. Y.	790	380	500
WHB	Sweeney Automotive and Electrical School	Kansas City, Mo.	730	411	500
WHD	West Va. University	Morgantown, W. Va.	833	360	250
WHK	The Radiovox Co.	Cleveland, Ohio	833	360	100
WHN	Ridgewood Times Prtg. & Pub. Co.	Ridgewood, L. I.	833	360	250

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Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WIAB	Joslyn Automobile Co.	Rockford, Ill.	833	360	50
WIAC	Galveston Tribune	Galveston, Tex.	833	360	100
WIAD	Ocean City Yacht Club	Ocean City, N. J.	1180	254	10
WIAE	Mrs. Robt. E. Zimmerman	Vinton, Iowa	833	360	40
WIAF	Gustav A. De Cortin	New Orleans, La.	1280	234	10
WIAH	Continental Rad. & Mfg. Co	Newton, Iowa	833	360	10
WIAI	The Heer Stores Co.	Springfield, Mo.	833	360	20
WIAJ	Fox River Valley Radio Supply Co.	Neenah, Wis.	1340	224	100
WIAK	Journal-Stockman Co.	Omaha, Nebr.	1080	278	200
WIAO	School of Eng. of Milwaukee	Milwaukee, Wis.	833	360	50
WIAQ	Chronicle Pub. Co.	Marion, Ind.	833	360	10
WIAR	Paducah Evening Sun	Paducah, Ky.	833	360	50
WIAS	Home Electric Co.	Burlington, Iowa	833	360	100
WIAT	Leon T. Noel	Tarkio, Mo.	833	360	100
WIAU	Amer. Trust & Savings Bk.	Le Mars, Iowa	833	360	15
WIAV	N. Y. Radio Laboratories	Binghamton, N. Y.	833	360	50
WIAW	Saginaw Radio & Elec. Co.	Saginaw, Mich.	833	360	100
WIAY	Woodward & Lothrop	Washington, D. C.	833	360	100
WIK	K. & L. Electric Co.	McKeesport, Pa.	833	360	500
WIL	Continental Elec. Sup. Co.	Washington, D. C.	833	360	10
WIP	Gimbel Brothers	Philadelphia, Pa.	590	509	500
WIZ	Cino Radio Mfg. Co.	Cincinnati, Ohio	833	360	100
WJAB	American Electric Co.	Lincoln, Nebr.	833	360	100
WJAD	Jackson's Radio Eng. Labs.	Waco, Tex.	833	360	100
WJAF	Press Pub. Co.	Muncie, Ind.	833	360	20
WJAG	Norfolk Daily News	Norfolk, Nebr.	833	360	100
WJAJ	Y. M. C. A.	Dayton, Ohio	833	360	175
WJAK	White Radio Laboratory	Stockdale, Ohio	833	360	60
WJAM	D. M. Perham	Cedar Rapids, Iowa	833	360	20
WJAN	Peoria Star Co.	Peoria, Ill.	1070	280	100
WJAP	Kelly-Duluth Co.	Duluth, Minn.	833	360	100
WJAQ	Capper Publications	Topeka, Kans.	833	360	100
WJAR	The Outlet Co.	Providence, R. I.	833	360	100
WJAS	Pittsburgh Radio Sup. Hse.	Pittsburgh, Pa.	833	360	500
WJAT	Kelley-Vawter Jewelry Co.	Marshall, Mo.	833	360	10
WJAX	Union Trust Co.	Cleveland, Ohio	770	390	500
WJAZ	Chicago Radio Lab.	Chicago, Ill.	670	448	500
WJD	Denison Univ.	Granville, Ohio	1310	229	50
WJH	White & Boyer Co.	Washington, D. C.	1100	273	50
WJX	DeForest Rad. Tel. & Tel. Co.	New York City	833	360	500
WJY	Radio Corp. of America	New York, N. Y.	740	405	500
WJZ	Radio Corp. of America	New York, N. Y.	660	455	500
WKAA	H. F. Paar	Cedar Rapids, Iowa	833	360	15
WKAC	The Lincoln Star	Lincoln, Nebr.	1090	275	100
WKAF	W. S. Radio Supply Co.	Wichita, Kans.	833	360	100
WKAH	Planet Radio Co.	W. Palm Beach, Fla.	833	360	50
WKAK	Okfuskee County News	Okemah, Okla.	833	360	325
WKAL	Gray & Gray	Orange, Texas	833	360	100
WKAN	United Battery Serv. Co.	Montgomery, Ala.	1330	226	20
WKAP	Dutee W. Flint	Cranston, R. I.	833	360	600
WKAQ	Radio Corp. of P. R.	San Juan, Porto Rico	833	360	500
WKAR	Mich. Agri. College	East Lansing, Mich.	833	360	100
WKAS	L. E. Lines Music Co.	Springfield, Mo.	833	360	20
WKAV	The Laconia Radio Club	Laconia, N. H.	833	360	50
WKAW	Turner Cycle Co.	Beloit, Wis.	1240	242	10
WKAX	Wm. A. MacFarlane	Bridgeport, Conn.	1300	231	15
WKAY	Brenau College	Gainesville, Ga.	833	360	20
WKC	Joseph M. Zamoiski Co.	Baltimore, Md.	833	360	50
WKN	Riechman-Crosby Co.	Memphis, Tenn.	833	360	25
WKY	WKY Radio Shop	Oklahoma City, Okla.	833	360	100
WLAC	N. Carolina State College	Raleigh, N. C.	833	360	500
WLAG	Cutting & Washington Radio Corp.	Minneapolis, Minn.	720	417	500
WLAH	Samuel Woodworth	Syracuse, N. Y.	1280	234	250

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Active Broadcasting Stations, June 15, 1923

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WLAJ	Waco Electric Supply Co..	Waco, Texas.....	833	360	150
WLAK	Vermont Farm Mach. Co..	Bellows Falls, Vt...	833	360	500
WLAL	Tulsa Radio Co.....	Tulsa, Okla.....	833	360	100
WLAN	Putnam Hardware Co.....	Houlton, Me.....	833	360	250
WLAP	W. V. Jordan.....	Louisville, Ky.....	833	360	100
WLAQ	A. E. Shilling.....	Kalamazoo, Mich...	833	360	10
WLAS	Central Radio Supply Co...	Hutchinson, Kans..	1230	244	20
WLAT	Radio & Specialty Co.....	Burlington, Iowa...	833	360	20
WLAV	The Electric Shop, Inc....	Pensacola, Fla.....	833	360	25
WLAW	N. Y. Police Dept.....	New York, City....	833	360	500
WLAX	Greencastle Community Broadcasting Sta.....	Greencastle, Ind....	1300	231	5
WLAY	North Commercial Co. of Alaska.....	Fairbanks, Alaska..	833	360	50
WLAZ	Hutton & Jones Elec. Co..	Warren, Ohio.....	1210	248	10
WLB	Univ. of Minnesota.....	Minneapolis, Minn..	833	360	100
WLK	Hamilton Mfg. Co.....	Indianapolis, Ind...	833	360	250
WLW	Crosley Manufacturing Co.	Cincinnati, Ohio....	970	309	500
WMAB	Radio Supply Co.....	OklahomaCity,Okla.	833	360	100
WMAC	J. Edward Page.....	Cazenovia, N. Y....	1150	261	200
WMAD	G. W. Chamberlain.....	Rock Port, Mo.....	833	360	10
WMAF	Round Hills Radio Corp...	Dartmouth, Mass...	833	360	500
WMAG	Tucker Elec. Co.....	Liberal, Kans.....	833	360	200
WMAH	General Supply Co.....	Lincoln, Nebr.....	1180	254	15
WMAJ	Drovers Telegram Co.....	Kansas City, Mo...	1090	275	25
WMAK	Norton Laboratories, Inc...	Lockport N. Y.....	833	360	250
WMAL	Trenton Hardware Co.....	Trenton, N. J.....	1070	256	15
WMAM	Beaumont Radio Equip. Co.	Beaumont, Tex.....	833	360	15
WMAN	Broad St. Baptist Church..	Columbus, Ohio....	1050	286	20
WMAP	Utility Battery Serv., Inc..	Easton, Pa.....	1220	246	50
WMAQ	Chicago Daily News.....	Chicago, Ill.....	670	448	500
WMAR	Waterloo Elec. Supply Co..	Waterloo, Iowa.....	833	360	100
WMAT	Paramount Radio Corp....	Duluth, Minn.....	833	360	250
WMAV	Alabama Polytechnic Inst..	Auburn, Ala.....	1200	250	250
WMAW	Wahpeton Elec. Co.....	Wahpeton. N. D...	833	360	50
WMAX	K. & K. Radio Supply Co..	Ann Arbor, Mich...	833	360	800
WMAY	Kingshighway Pres. Church	St. Louis, Mo.....	833	360	100
WMAZ	Mercer University.....	Macon, Ga.....	1120	268	50
WMC	The Commercial Pub. Co..	Memphis, Tenn....	600	500	500
WMH	Precision Equip. Co.....	Cincinnati, Ohio....	1210	248	10
WMU	Doubleday-Hill Elec. Co...	Washington, D. C..	1150	261	100
WNAB	Park City Daily News....	Bowling Green, Ky.	833	360	100
WNAC	Shepard Stores.....	Boston, Mass.....	833	360	100
WNAD	Oklahoma Radio Engr. Co.	Norman, Okla.....	833	360	100
WNAL	R. J. Rockwell.....	Omaha, Nebr.....	833	360	300
WNAM	Ideal Apparatus Co.....	Evansville, Ind.....	833	360	100
WNAN	Syracuse Radio Tel. Co...	Syracuse, N. Y.....	1050	286	100
WNAP	Wittenberg College.....	Springfield, Ohio....	833	360	100
WNAQ	Charleston Radio Elec. Co.	Charleston, S. C....	833	360	10
WNAR	C. C. Rhodes.....	Butler, Mo.....	833	360	20
WNAS	Texas Radio Corp. & Austin Statesman.....	Austin, Texas.....	833	360	100
WNAT	Lennig Bros. Co.....	Philadelphia, Pa...	833	360	250
WNAV	Peoples Tel. & Tel. Co....	Knoxville, Tenn....	833	360	50
WNAW	Peninsular Radio Club....	Fort Monroe, Va...	833	360	20
WNAX	Dakota Radio App. Co....	Yankton, S. D.....	1230	244	100
WNAY	Ship Owners Radio Service	Baltimore, Md.....	833	360	10
WNJ	Shotten Radio Mfg. Co...	Albany, N. Y.....	833	360	100
WOAA	Dr. Walter Hardy.....	Ardmore, Okla.....	833	360	20
WOAB	Valley Radio.....	Grand Forks,N. Dak.	833	360	5
WOAC	Maus Radio Co.....	Lima, Ohio.....	1130	266	100
WOAD	Friday Battery & Elec. Co.	Sigourney, Iowa....	833	360	50
WOAE	Midland College.....	Fremont, Nebr.....	833	360	20
WOAF	Tyler Commercial College..	Tyler,Texas.....	833	360	10
WOAG	Apollo Theatre.....	Belvidere, Ill.....	1340	224	20

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Active Broadcasting Stations, June 15, 1923

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WOAH	Palmetto Radio Shop	Charleston, S. C.	833	360	100
WOAI	Southern Equip. Co.	San Antonio, Texas.	780	385	500
WOAJ	Ervins Electrical Co.	Parsons, Kans.	833	360	15
WOAK	Collins Hardware Co.	Frankfort, Ky.	1250	240	10
WOAL	William E. Woods	Webster Grove, Mo.	833	360	500
WOAN	James D. Vaughan	Lawrenceburg, Tenn.	833	360	200
WOAO	Lyradion Mfg. Co.	Mishawaka, Ind.	833	360	50
WOAP	Kalamazoo College	Kalamazoo, Mich.	833	360	50
WOAQ	Portsmouth Kiwanis Club.	Portsmouth, Va.	833	360	15
WOAR	Henry P. Lundskow	Kenosha, Wis.	833	360	50
WOAS	Bailey's Radio Shop.	Middletown, Conn.	833	360	50
WOAT	I. X. L. Radio Store	Wilmington, Del.	833	360	50
WOAU	Sowder Bolling Piano Co.	Evansville, Ind.	833	360	100
WOAV	Pennsylvania Nat. Guard	Erie, Pa.	1240	242	100
WOAW	Sovereign Camp, Woodmen of the World	Omaha, Nebr.	570	526	500
WOAX	Franklyn J. Wolff	Trenton, N. J.	1250	240	100
WOAZ	Penick Hughes Co.	Stamford, Texas.	833	360	100
WOC	Palmer Sch. of Chiropractic	Davenport, Iowa.	620	484	500
WOI	Iowa State College	Ames, Iowa.	833	360	100
WOK	Ark. Light & Power Co.	Pine Bluff, Ark.	833	360	500
WOO	John Wanamaker	Philadelphia, Pa.	590	509	500
WOQ	Western Radio Co.	Kansas City, Mo.	833	360	500
WOR	L. Bamberger & Co.	Newark, N. J.	740	405	500
WOS	Mo. State Marketing Bur.	Jefferson City, Mo.	833	360	500
WOU	Metropolitan Utilities District	Omaha, Nebr.	833	360	50
WPAA	Anderson & Webster Elec. Co.	Wahoo, Nebr.	833	360	150
WPAB	Pennsylvania State College	State College, Pa.	833	360	500
WPAC	Donaldson Radio Co.	Okmulgee, Okla.	833	360	200
WPAD	W. A. Wieboldt & Co.	Chicago, Ill.	833	360	100
WPAF	Peterson's Radio Co.	Council Bluffs, Iowa	833	360	10
WPAH	Wisconsin Dept. of Markets	Waupaca, Wis.	833	360	250
WPAJ	Doolittle Radio Corp.	New Haven, Conn.	1120	268	10
WPAK	Agri. College of N. Dakota.	Fargo, N. Dakota.	833	360	50
WPAL	Superior Radio & Tel. Eq. Co.	Columbus, Ohio.	1050	286	100
WPAM	Auerbach & Geuttel.	Topeka, Kans.	833	360	5
WPAP	Theodore D. Phillips.	Winchester, Ky.	833	360	10
WPAQ	General Sales & Eng. Co.	Frostburg, Md.	833	360	10
WPAR	Ward Bat. & Rad. Co.	Beloit, Kans.	833	360	10
WPAS	J. & M. Electric Co.	Amsterdam, N. Y.	833	360	20
WPAT	Saint Patrick's Cathedral	El Paso, Texas.	833	360	10
WPAU	Concordia College	Moorhead, Minn.	833	360	20
WPAY	Bangor Radio Lab.	Bangor, Me.	833	360	20
WPAZ	Dr. John R. Koch	Charleston, W. Va.	1100	273	10
WPE	Central Radio Co.	Independence, Mo.	833	360	100
WPG	Nushawg Poultry Farm	New Lebanon, Ohio.	833	360	30
WPI	Elec. Supply Co.	Clearfield, Pa.	833	360	20
WPO	United Equipment Co.	Memphis, Tenn.	833	360	40
WQAA	Horace A. Beale, Jr.	Parkesburg, Pa.	883	360	500
WQAB	Southwest Missouri State Teachers College	Springfield, Mo.	1270	236	10
WQAC	Gish Radio Service	Amarillo, Tex.	833	360	100
WQAD	Whitall Elec. Co.	Waterbury, Conn.	1240	242	50
WQAE	Moore Radio News Station	Springfield, Vt.	833	360	50
WQAF	Sandusky Register	Sandusky, Ohio.	1250	240	5
WQAH	Brock-Anderson Elec. E. Co.	Lexington, Ky.	1180	254	10
WQAJ	Ann Arbor Times News.	Ann Arbor, Mich.	833	360	300
WQAK	Appel-Higley Elec. Co.	Dubuque, Iowa.	833	360	10
WQAL	Coles County Tel. & Tel. Co.	Mattoon, Ill.	1160	258	10
WQAM	Elec. Equip. Co.	Miami, Fla.	833	360	100
WQAN	Scranton Times	Scranton, Pa.	833	360	100

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Active Broadcasting Stations, June 15, 1923

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WQAO	Calvary Baptist Church...	New York City....	833	360	100
WQAQ	Abilene Daily Reporter....	Abilene, Texas.....	833	360	50
WQAS	Prince-Walter Co.....	Lowell, Mass.....	1130	266	100
WQAT	Radio Equipment Corp....	Richmond, Va.....	833	360	50
WQAV	Huntington & Guerry, Inc.	Greenville, S. C....	1160	258	15
WQAW	Catholic Univ. of America..	Washington, D. C..	1270	236	50
WQAX	Radio Equip. Co.....	Peoria, Ill.....	833	360	20
WQAY	Gaston Music & Furn. Co.	Hastings, Neb.....	833	360	20
WQAZ	Greensboro Daily News...	Greensboro, N. C...	833	360	30
WRAA	Rice Institute.....	Houston, Tex.....	833	360	100
WRAB	Savannah Board of Pub. Education.....	Savannah, Ga.....	833	360	100
WRAC	State Normal School.....	Mayville, N. Dak..	833	360	50
WRAD	Taylor Radio Shop.....	Marion, Kans.....	833	360	10
WRAF	Radio Club, Inc.....	Laporte, Ind.....	1340	224	10
WRAH	Stanley N. Read.....	Providence, R. I....	833	360	10
WRAK	Economy Light Co.....	Escanaba, Mich....	833	360	200
WRAL	Northern States Power Co.	St. Croix Falls, Wis.	1210	248	100
WRAM	Lombard College.....	Galesburg, Ill.....	833	360	50
WRAN	Black Hawk Elec. Co.....	Waterloo, Iowa.....	1310	229	20
WRAO	Radio Service Co.....	St. Louis, Mo.....	833	360	100
WRAP	Winter Pk. Elec. Const. Co.	Winter Park, Fla...	833	360	20
WRAR	Jacob Carl Thomas.....	David City, Nebr...	1130	226	20
WRAS	Radio Supply Co.....	McLeansboro, Ill...	833	360	20
WRAU	Amarillo Daily News.....	Amarillo, Tex.....	833	360	10
WRAV	Antioch College.....	Yellow Springs, Ohio	833	360	20
WRAW	Horace D. Good.....	Reading, Pa.....	1260	238	10
WRAX	Flexon's Garage.....	Gloucester City,N.J.	1120	268	50
WRAY	Radio Sales Corp.....	Scranton, Pa.....	833	360	100
WRK	Doron Bros. Elec. Co.....	Hamilton, Ohio....	833	360	500
WRL	Union College.....	Schenectady, N.Y...	833	360	500
WRM	Univ. of Illinois.....	Urbana, Ill.....	833	360	100
WRP	Federal Inst. of Radio Tel.	Camden, N. J.....	833	360	100
WRR	City of Dallas, Police & Fire Signal Dept.....	Dallas, Tex.....	833	360	20
WRW	Tarrytown Radio Research Lab.....	Tarrytown, N. Y...	1100	273	150
WSAA	B. S. Sprague Elec. Co.....	Marietta, Ohio.....	833	360	25
WSAB	Southeast Missouri State Teachers' College.....	Cape Girardeau, Mo.	833	360	100
WSAC	Clemson Agri. College.....	Clemson College, S. C.....	833	360	500
WSAD	J. A. Foster Co.....	Providence, R. I....	1150	261	50
WSAH	A. G. Leonard, Jr.....	Chicago, Ill.....	1210	248	500
WSAI	U. S. Playing Card Co.....	Cincinnati, Ohio....	970	309	500
WSAJ	Grove City College.....	Grove City, Pa.....	833	360	100
WSAL	Franklin Elec. Co.....	Brookville, Ind.....	1220	246	20
WSAP	Seventh Day Adventist Ch.	New York, N. Y....	833	360	250
WSAT	The Plainview Elec. Co....	Plainview, Texas...	833	360	20
WSAV	Clifford W. Vick Radio Construction Co.....	Houston, Tex.....	833	360	100
WSB	Atlanta Journal.....	Atlanta, Ga.....	700	429	500
WSL	J. & M. Electric Co.....	Utica, N. Y.....	1100	273	100
WSY	Alabama Power Co.....	Birmingham. Ala...	833	360	500
WTAC	Penn Traffic Co.....	Johnstown, Pa.....	833	360	150
WTAG	Kern Music Co.....	Providence, R. I....	1160	258	10
WTAK	The Swan-Bower Co.....	Steubenville, Ohio..	1130	266	20
WTAS	Charles E. Erbstein.....	Elgin, Ill.....	1090	275	500
WTAU	Ruegy Battery & Elec. Co..	Tecumseh, Nebr....	833	360	10
WTAW	Agri. & Mech. College of Texas.....	College Station,Tex.	1180	254	50
WTG	Kans. State Agri. College...	Manhattan, Kans..	833	360	500
WTP	George M. McBride.....	Bay City, Mich....	833	360	10
WWAC	Sanger Bros.....	Waco, Tex.....	833	360	50
WWAD	Wright and Wright, Inc...	Philadelphia, Pa....	833	360	200

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Active Broadcasting Stations, June 15, 1923

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
WWAX	Worman Bros.	Laredo, Tex.	833	360	100
WWAY	Marigold Gardens	Chicago, Ill.	833	360	500
WWB	Daily News Printing Co.	Canton, Ohio	833	360	200
WWI	Ford Motor Co.	Dearborn, Mich.	1100	273	50
WWJ	The Detroit News	Detroit, Mich.	580	517	500
WWL	Loyola University	New Orleans, La.	833	360	50
WWZ	John Wanamaker	New York City	833	360	50

Class B Stations

KFDB	Mercantile Trust Co. of California	San Francisco, Calif.	590	509	750
KFI	Earle C. Anthony, Inc.	Los Angeles, Calif.	640	469	500
KGW	The Portland Morning Oregonian	Portland, Oregon	610	492	500
KHJ	Times-Mirror Co.	Los Angeles, Calif.	760	395	500
KPO	Hale Bros., Inc.	San Francisco, Calif.	710	423	500
KSD	Post Dispatch	St. Louis, Mo.	550	546	500
KYW	Westinghouse E. & M. Co.	Chicago, Ill.	870	345	1000
WBAP	Wortham-Carter Pub. Co.	Fort Worth, Texas	630	476	500
WBAV	Erner & Hopkins Co.	Columbus, Ohio	770	390	500
WBAY	Western Elec. Co.	New York, N. Y.	610	492	500
WBZ	Westinghouse E. & M. Co.	Springfield, Mass.	890	337	750
WCAE	Kaufman & Baer Co.	Pittsburgh, Pa.	650	461	500
WCBD	Wilbur Glenn Voliva	Zion City, Ill.	870	345	500
WCX	Detroit Free Press	Detroit, Mich.	580	517	500
WDAF	Kansas City Star	Kansas City, Mo.	730	411	500
WDAR	Lit Brothers	Philadelphia, Pa.	760	395	500
WDT	Ship Owners Radio Service	New York, N. Y.	740	405	500
WEAF	American Tel. & Tel. Co.	New York, N. Y.	610	492	500
WFAA	A. H. Belo & Co., Publishers	Dallas, Tex.	630	476	500
WFI	Strawbridge & Clothier	Philadelphia, Pa.	760	395	500
WGM	Atlanta Constitution	Atlanta, Ga.	700	429	500
WGY	General Electric Co.	Schenectady, N. Y.	790	380	1000
WHAS	Courier-Journal & Louisville Times	Louisville, Ky.	750	400	500
WHAZ	Rensselaer Polytechnic Inst.	Troy, N. Y.	790	380	500
WHB	Sweeney Automotive and Electrical School	Kansas City, Mo.	730	411	500
WIP	Gimbel Bros.	Philadelphia, Pa.	590	509	500
WJAX	Union Trust Co.	Cleveland, Ohio	770	390	500
WJAZ	Chicago Radio Lab.	Chicago, Ill.	670	448	500
WJY	Radio Corp. of America	New York, N. Y.	740	405	500
WJZ	Radio Corp. of America	New York, N. Y.	660	455	500
WLAG	Cutting & Washington Radio Corp.	Minneapolis, Minn.	720	417	500
WLW	Crosley Mfg. Co.	Cincinnati, Ohio	970	309	500
WMAQ	Chicago Daily News	Chicago, Ill.	670	448	500
WMC	The Commercial Pub. Co.	Memphis, Tenn.	600	500	500
WOAI	Southern Equip. Co.	San Antonio, Tex.	780	385	500
WOAW	Sovereign Camp, Woodmen of the World	Omaha, Nebr.	570	526	500
WOC	Palmer School of Chiropractic	Davenport, Iowa	620	484	500
WOO	John Wanamaker	Philadelphia, Pa.	590	509	500
WOR	L. Bamburger & Co.	Newark, N. J.	740	405	500
WSAI	U. S. Playing Card Co.	Cincinnati, Ohio	970	309	500
WSB	Atlanta Journal	Atlanta, Ga.	700	429	500
WWJ	The Detroit News	Detroit, Mich.	580	517	500

Class D—Broadcasting Development

KDKA	Westinghouse Elec. & Mfg. Co.	East Pittsburgh, Pa.	920	326	1000

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List of Canadian Radio Telephone Broadcasting Stations

Active Broadcasting Stations, June 15, 1923

Call Signal	Owner of Station	Location of Station	Frequency Kilocycles	Wave Length Meters	Rating Oscill. Watts
CFAC	Radio Corp. of Calgary,Ltd	Calgary Alberta....	697	430	1000
CFBC	King's Radio Shop.....	Timmins, Ont.....	666	450	50
CFCA	Star Pub. & Printing Co..	Toronto, Ont.....	750	400	1000
CFCB	Marconi W/T. Co.....	Vancouver, B. C....	681	440	250
CFCD	Can. Westinghouse Co.,Ltd	Winnipeg, Man....	681	440	
CFCE	Marconi W/T Co.....	Halifax, N. S.....	681	440	250
CFCF	Marconi W/T Co.....	Montreal, Que.....	681	440	250
CFCH	Abitibi Power & Paper Co.	Iroquois Falls, Ont..	750	400	125
CFCI	Motor Products Corp.....	Walkerville, Ont....	681	440	1000
CFCJ	La Cie L'Evenement.....	Quebec, Que.....	731	410	10
CFCN	W. W. Grant Radio, Ltd...	Calgary, Alberta...	681	440	375
CFCX	The London Advertiser....	London, Ont.....	681	440	
CFPC	Int. Radio Development Co.	Fort Frances, Ont..	750	400	50
CFTC	The Bell Telephone Co....	Toronto, Ont.....			1000
CFUC	University of Montreal....	Montreal, Que.....	750	400	1000
CFVC	Roy Russell Brown.....	Courtenay, B. C....	666	450	125
CFYC	V. W. Odlum.....	Vancouver, B. C....	750	400	50
CFZC	Can. Westinghouse Co.,Ltd.	Montreal, Que.....	750	400	
CHAC	Radio Engineers, Ltd.....	Halifax, N. S.....	714	420	50
CHBC	Albertan Pub. Co., Ltd....	Calgary, Alberta...	731	410	250
CHCA	Radio Corporation of Vancouver, Ltd.....	Vancouver, B. C...	697	430	100
CHCB	Marconi W/T Co.....	Toronto, Ont.....	681	440	250
CHCC	Can. Westinghouse Co.,Ltd.	Edmonton, Alberta.	750	400	
CHCF	Rad.Corp. of Winnipeg,Ltd.	Winnipeg, Man.....	697	430	1000
CHCQ	Western Radio Co.....	Calgary, Alberta...	750	400	10
CHCS	London Radio Shoppe.....	London, Ont.....	731	410	250
CHCX	B. L. Silver.....	Montreal, Que.....	714	420	100
CHCZ	The Globe Printing Co....	Toronto, Ont.....	714	420	
CHFC	John Millen & Sons, Ltd...	Toronto, Ont.....	731	410	100
CHIC	Can. Westinghouse Co.,Ltd.	Hamilton, Ont.....	750	400	
CHOC	Can. Westinghouse Co.,Ltd.	Vancouver, B. C....	750	400	200
CHVC	Metropolitan Motors.....	Toronto, Ont.....	731	410	20
CHXC	J. R. Booth, Jr.....	Ottawa, Ont.....	666	450	275
CHYC	Northern Elec. Co.....	Montreal, Que.....	731	410	1000
CJBC	Dupuis Freres.....	Montreal, Que.....	714	420	250
CJCA	Edmonton Journal, Ltd....	Edmonton, Alberta.	666	450	250
CJCB	J. G. Bennett.....	Nelson, B. C.....	750	400	20
CJCD	T. Eaton Co., Ltd.....	Toronto, Ont.....	731	410	15
CJCE	Sprott-Shaw Radio Co....	Vancouver, B. C...	714	420	20
CJCF	The News Record, Ltd.....	Kitchener, Ont.....	714	420	30
CJCG	Manitoba Free Press.....	Winnipeg, Man.....	731	410	800
CJCH	The United Farmers of Ont.	Toronto, Ont.....	731	410	
CJCI	McLean, Holt & Co., Ltd..	St. John, N. B.....	750	400	50
CJCN	Simons, Agnew Co.....	Toronto, Ont.....	731	410	1000
CJCS	Eastern Telep. & Teleg.Co.	Halifax, N. S.....	731	410	750
CJCY	Edmund Taylor.....	Calgary, Alberta...	714	420	
CJGC	London Free Press Prtg. Co.	London, Ont.....	697	430	100
CJNC	Tribune Newspaper Co....	Winnipeg, Man.....	750	400	250
CJSC	The Evening Telegram....	Toronto, Ont.....	697	430	250
CKAC	La Presse Pub. Co.....	Montreal, Que.....	697	430	1000
CKCB	T. Eaton Co., Ltd.....	Winnipeg, Man.....	666	450	
CKCD	Vancouver Daily Province.	Vancouver, B. C....	731	410	250
CKCE	Canadian Indep. Tel. Co...	Toronto, Ont.....	666	450	1000
CKCK	Leader Publishing Co., Ltd. of Regina.....	Regina, Sask.....	714	420	1000
CKCR	Jones Elec. Co.....	St. John, N. B.....	750	400	10
CKCS	The Bell Telephone Co....	Montreal, Que.....			1000
CKCZ	Can. Westinghouse Co.,Ltd.	Toronto, Ont.....	714	420	
CKKC	Radio Equip. and SupplyCo	Toronto, Ont.....	731	410	100
CKOC	WentworthRadio SupplyCo	Hamilton, Ont.....	731	410	20
CKQC	Radio SupplyCo., of London	London, Ont.....	731	410	25
CKZC	Salton Radio Eng. Co.....	Winnipeg, Man....	714	420	50

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GEOGRAPHICAL LIST OF BROADCASTING STATIONS

June 15, 1923

(See Alphabetical List for details)

Alabama

Auburn.....WMAV
Birmingham...WSY
Mobile.....WEAP
Montgomery...WKAN

Alaska

Fairbanks.....WLAY

Arizona

Phoenix.....KDYW
KFAD
KFBC
Tucson.....KFDH

Arkansas

Fayetteville....KFDV
Fort Smith....WCAC
WGAR
Little Rock....WCAV
WEAX
Pine Bluff.....WOK

California

Altadena.....KGO
Bakersfield.....KDZB
Berkeley.....KQI
KRE
El Monte.....KUY
Eureka.....KNI
Fresno.....KMJ
Hanford.....KFBD
Hollywood.....KFAR
Long Beach....KSS
Los Angeles....KDZF
KFI
KHJ
KJS
KNN
KNV
KUS
KWH
Los Gatos.....KFHQ
Modesto.....KXD
Monterey.....KLN
Oakland.....KLS
KLX
KZM
Reedley.....KMC
Richmond.....KFCM
Sacramento....KFBK
San Antonio....KFCL
San Diego.....KDPT
KDYM
KFBC
KFFA
San Francisco..KDZG
KDZW
KDZX
KFDB
KPO
KSL
KUO
San Jose.....KFAQ
KQW
San Luis Obispo KFBE
Santa Ana.....KFAW
Santa Barbara..KFHJ
Stanford Univ..KFGH
Stockton.....KJQ
KWG
Sunnyvale.....KJJ
Taft.....KFEB
Venice.....KFAV

Colorado

Boulder.....KFAJ
Colorado Sprgs.KFCK
KFFQ
Denver.....KDZQ
KFAF
KFDL
KFEL
KFEP
KFIC
KFLE
KLZ
KOA
Greeley.....KFJD
KFKA
Gunnison.....KFHA
Lakeside.....KFKH
Pueblo.....KFGB
Trinidad.....KFBS

Connecticut

Bridgeport.....WKAX
Hartford.....WDAK
Middletown....WOAS
New Haven....WPAJ
Storrs.....WABL
Waterbury.....WQAD

Delaware

Wilmington....WHAV
WOAT

District of Columbia

Washington....WABE
WDM
WEAS
WHAQ
WIAY
WIL
WJH
WMU
WQAW

Florida

Jacksonville....WABG
WDAL
Miami.....WFAW
WQAM
Pensacola.....WGAN
WLAV
Tampa.....WDAE
WHAW
W. Palm Beach.WKAH
Winter Park...WRAP

Georgia

Atlanta.....WGM
WSB
College Park...WDAJ
Gainesville.....WKAY
Macon.....WMAZ
Savannah.....WHAO
WRAB

Hawaii

Honolulu.....KDYX
KGU
KYQ
Lihue.....KFHS

Idaho

Boise.....KFAU
KFFB
KFDD
KFFJ
Kellogg.....KFEY
Moscow.....KFAN

Illinois

Belvidere.....WOAG
Carthage.....WCAZ
Chicago.....KYW
WAAF
WBU
WDAP
WJAZ
WMAQ
WPAD
WSAH
WWAY
Decatur.....WBAO
WHAP
Elgin.....WTAS
Galesburg.....WRAM
Lake Forest....WABA
Mattoon.....WQAL
McLeansboro..WRAS
Mt. Vernon....WABF
Quincy.....WCAW
Rockford.....WIAB
Peoria.....WJAN
WQAX
Sterling.....WBBC
Tuscola.....WDZ
Urbana.....WRM
Zion City.....WCBD

Indiana

Anderson.....WABC
Brookville.....WSAL
Evansville.....WNAM
WOAU
Greencastle....WLAX
Huntington....WHAY
Indianapolis...WLK
Laporte.....WRAF
Marion.....WIAQ
Mishawaka....WOAO
Muncie.....WJAF
South Bend....WABJ
WGAZ
West Lafayette.WBAA

Iowa

Ames.....WOI
Boone.....KFGQ
Burlington.....WIAS
WLAT
Cedar Rapids..WJAM
WKAA
Centerville.....WDAX
Council Bluffs..WPAF
Davenport.....WHAI
WOC
Des Moines....KFDP
WGF
Dubuque.....WQAK
Fort Dodge....KFER
WEAB
Gladbrook.....KFIK
Iowa City.....WHAA
Lamoni.....KFFV
Le Mars.....KFCY
WIAU
Marshalltown..KFJB
Newton.....WIAH
Oskaloosa.....KFHL

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Geographical List of Broadcasting Stations, June 15, 1923
(See Alphabetical List for details)

Sigourney.....WOAD
Sioux City.....WEAU
WHAE
Vinton.....WIAE
Waterloo.....WHAC
WMAR
WRAN

Kansas

Anthony.....WBL
Atwood.....WEAD
Beloit.....WPAR
Chency.....KFGP
Emporia.....WAAZ
Hutchinson....WLAS
Iola.....KFID
Liberal.....WMAG
Lindsborg.....WDAD
Louisburg.....KFIL
Manhattan....WTG
Marion.....WRAD
Parsons.....WOAJ
Topeka.....WJAQ
WPAM
Wichita.....KFHI
WAAP
WEAH
WEY
WKAF

Kentucky

Bowling Green.WNAB
Frankfort.....WOAK
Lexington.....WQAH
Louisville.....WHAS
WLAP
Paducah.....WIAR
Winchester....WPAP

Louisiana

Alexandria.....KFFY
Baton Rouge...KFGC
New Orleans...WAAB
WAAC
WCAG
WGV
WIAF
WWL
Shreveport.....KFDX
KFHF
WGAQ

Maine

Bangor.....WABI
WPAY
Houlton.....WLAN

Maryland

Baltimore.....WCAO
WEAR
WKC
WNAY
Frostburg.....WPAQ

Massachusetts

Boston.....WNAC
Dartmouth....WMAF
Lowell.....WQAS
MedfordHillisideWGI
New Bedford...WDAU
Springfield.....WBZ
Worcester.....WABK
WCN
WDAS

Michigan

Ann Arbor.....WMAX
WQAJ
Bay City.....WTP
Berrien Springs KFGZ
Dearborn.....WWI
Detroit.....KOP
WCX
WWJ
East Lansing...WKAR
Escanaba.....WRAK
Flint.....WEAA
Kalamazoo....WLAQ
WOAP
Lansing.....WHAL
Saginaw.....WABM
WIAW

Minnesota

Baudette.....KFGY
Duluth.....WJAP
WMAT
Hutchinson....WFAN
Minneapolis....KFDZ
KFEX
WAAL
WBAD
WBAH
WCAS
WCE
WLAG
WLB
Moberly.....KFFP
Moorhead.....WPAU
Northfield.....WCAL
St. Cloud.....WFAM
St. Paul.....WAAH

Missouri

Butler.....WNAR
Cameron.....WFAQ
Cape Girardeau WSAB
Columbia.....WAAN
Independence..WPE
Jefferson City..WOS
Joplin.....WHAH
Kansas City...WDAF
WHB
WMAJ
WOQ
Marshall.....WJAT
Rock Port.....WMAD
St. Joseph.....KFHD
WEAK
St. Louis.....KFEZ
KFGJ
KFIB
KSD
WCK
WEB
WEW
WMAY
WRAO
Springfield.....WIAI
WKAS
WQAB
Tarkio.....WIAT
Webster Grove.WOAL

Montana

Billings.....KFCH
Bozeman.....KFDO
Butte.....KFAP
Great Falls....KDYS
Havre.....KFBB

Nebraska

David City....WRAR
Fremont.....WOAE
Grand Island...KFJA
Hastings.....WQAY
Kearney.....KFHP
Lincoln.....KFDU
WFAV
WJAB
WKAC
WMAH
Norfolk.....WJAG
Oak.....KFEQ
Omaha.....KFCZ
KFFX
WAAW
WIAK
WNAL
WOAW
WOU
Rushville.....WEAV
Tecumseh.....WTAU
Univ. Place....WCAJ
Utica.....KFGV
Wahoo.....WPAA
York.....KFDR

Nevada

Reno.....KDZK
Sparks.....KFFR

New Hampshire

Laconia.....WKAV

New Jersey

Camden.....WRP
Gloucester City WRAX
Moorestown...WBAF
Newark.....WAAM
WBS
WOR
North Plainfield WEAM
Ocean City....WIAD
Paterson.....WBAN
Trenton.....WMAL
WOAX

New Mexico

Roswell.....KNJ
State College...KOB

New York

Albany.....WNJ
Amsterdam....WPAS
Binghamton...WIAV
Buffalo.....WGR
Canton.....WCAD
Cazenovia.....WMAC
Ithaca.....WEAI
Lockport.....WMAK
Newburgh.....WCAB
New York City.WBAY
WDT
WEAF
WJX
WJY
WJZ
WLAW
WQAO
WSAP
WWZ

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Geographical List of Broadcasting Stations, June 15, 1923
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Poughkeepsie...WFAF
Ridgewood,L.I.WHN
Rochester.....WABO
WHAM
Schenectady...WGY
WRL
Syracuse.....WDAI
WFAB
WLAH
WNAN
Tarrytown.....WRW
Troy.....WHAZ
Utica.....WSL
Waterford.....WFAG

North Carolina

Asheville.....WFAJ
Charlotte.....WBT
Greensboro....WQAZ
Raleigh.....WLAC

North Dakota

Fargo.....WDAY
WPAK
Grand Forks...WOAB
Mayville.....WRAC
Wahpeton.....WMAW

Ohio

Canton.....WWB
Cincinnati.....WAAD
WHAG
WIZ
WLW
WMH
WSAI
Cleveland.....KDPM
WHK
WJAX
Columbus.....WBAV
WCAH
WEAO
WMAN
WPAL
Dayton.....WABD
WJAJ
Granville.....WJD
Greenville.....WCBB
Hamilton.....WBAU
WRK
Lima.....WOAC
Marietta.....WBAW
WSAA
Newark.....WBBA
New Lebanon..WPG
Sandusky.....WABH
WQAF
Springfield.....WNAP
Stockdale.....WJAK
Steubenville...WTAK
Warren.....WLAZ
Washington
Court House..WGAX
Wooster.....WGAU
Yellow Springs.WRAV
Youngstown...WAAY
WDBF

Oklahoma

Ardmore.....WOAA
Chickasha.....KFGD
Okemah.....WKAK
Oklahoma City.WKY
WMAB
Okmulgee.....WPAC
Norman.....WNAD
Tulsa.....WEH
WLAL

Oregon

Arlington.....KFGL
Baker.....KFDA
Corvallis.....KFDJ
Eugene.....KFAT
Hillsboro.....KFFO
Hood River....KFHB
KQP
Marshfield.....KFBH
Medford.....KFAY
Pendleton.....KFFE
Portland.....KDYQ
KFEC
KFIF
KGG
KGN
KGW
Salem.....KFCD

Pennsylvania

Allentown.....WCBA
Altoona.....WGAW
Clearfield.....WPI
Easton.....WMAP
East PittsburghKDKA
Erie.....WOAV
Grove City....WSAJ
Harrisburg.....WABB
WBAK
Johnstown.....WTAC
Lancaster.....WDBC
WGAL
McKeesport...WIK
Parkesburg.....WQAA
Philadelphia....WCAU
WDAR
WFI
WGL
WIP
WNAT
WOO
WWAD
Pittsburgh.....KQV
WCAE
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WOAH
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Vermillion WEAJ
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WPO

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Beaumont.....WMAM
College Station..WTAW
Dallas.....KFFZ
WDAO
WFAA
WRR
El Paso.....WDAH
WPAT
Fort Worth....WBAP
Galveston.....WHAB
WIAC
Houston.....KFCV
WCAK
WEAY
WEV
WRAA
WSAV
Laredo.....WWAX
Orange.....KFGX
WKAL
Plainview.....WSAT
Port Arthur....WFAH
San Antonio...WCAR
WOAI
Stanford.....WOAZ
Tyler.....WOAF
Waco.....WJAD
WLAJ
WWAC

Utah

Ogden.....KFCP
Salt Lake City..KDYL
KZN

Vermont

Bellows Falls...WLAK
Burlington.....WCAX
Springfield.....WQAE

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WJAB
WKAC
WMAH
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WNAL
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Rushville.....WEAV
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WPAK
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Wahpeton.....WMAW

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Cincinnati.....WAAD
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WIZ
WLW
WMH
WSAI
Cleveland.....KDPM
WHK
WJAX
Columbus.....WBAV
WCAH
WEAO
WMAN
WPAL
Dayton.....WABD
WJAJ
Granville.....WJD
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Lima.....WOAC
Marietta.....WBAW
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Newark.....WBBA
New Lebanon..WPG
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Steubenville....WTAK
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Wooster.....WGAU
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Chickasha.....KFGD
Okemah.....WKAK
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Okmulgee.....WPAC
Norman.....WNAD
Tulsa.....WEH
WLAL

Oregon

Arlington.....KFGL
Baker.....KFDA
Corvallis.....KFDJ
Eugene.....KFAT
Hillsboro.....KFFO
Hood River....KFHB
KQP
Marshfield.....KFBH
Medford.....KFAY
Pendleton.....KFFE
Portland.....KDYQ
KFEC
KFIF
KGG
KGN
KGW
Salem.....KFCD

Pennsylvania

Allentown.....WCBA
Altoona.....WGAW
Clearfield.....WPI
Easton.....WMAP
East PittsburghKDKA
Erie.....WOAV
Grove City....WSAJ
Harrisburg.....WABB
WBAK
Johnstown.....WTAC
Lancaster.....WDBC
WGAL
McKeesport...WIK
Parkesburg.....WQAA
Philadelphia....WCAU
WDAR
WFI
WGL
WIP
WNAT
WOO
WWAD
Pittsburgh.....KQV
WCAE
WHAF
WJAS
Reading.....WBBD
WRAW
Scranton.....WLAO
WQAN
WRAY
State College...WPAB
Villanova.....WCAM
Wilkes-Barre...WBAX

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San Juan.....WKAQ

Rhode Island

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Edgewood.....WEAG
Providence.....WEAN
WJAR
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WSAD
WTAG

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Vermillion.....WEAJ
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Lawrenceburg..WOAN
Memphis.....WKN
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Texas

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Amarillo.....WDAG
WQAC
WRAU
Austin.....WCM
WNAS
Beaumont.....WMAM
College Station.WTAW
Dallas.....KFFZ
WDAO
WFAA
WRR
El Paso.....WDAH
WPAT
Fort Worth....WBAP
Galveston.....WHAB
WIAC
Houston.....KFCV
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WEAY
WEV
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WSAV
Laredo.....WWAX
Orange.....KFGX
WKAL
Plainview.....WSAT
Port Arthur....WFAH
San Antonio...WCAR
WOAI
Stanford.....WOAZ
Tyler.....WOAF
Waco.....WJAD
WLAJ
WWAC

Utah

Ogden.....KFCP
Salt Lake City..KDYL
KZN

Vermont

Bellows Falls...WLAK
Burlington.....WCAX
Springfield.....WQAE

Virginia

Fort Monroe...WNAW
Portsmouth....WOAQ
Richmond.....WQAT

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Geographical List of Broadcasting Stations, June 15, 1923
(See Alphabetical List for details)

Washington
Aberdeen.....KNT
Bellingham....KDZR
Everett.....KFBL
Lacey.....KGY
Neah Bay.....KFHH
Pullman.....KFAE
Seattle.....KDZE
KDZT
KFHR
KHQ
KJR
KTW
Spokane.....KFDC
KFIO
KFZ
Tacoma.....KFBG
KFEJ
KGB
KMO
Walla Walla....KFCF
Wenatchee.....KDZI
KZV
Yakima.....KFIQ

West Virginia
Charleston.....WPAZ
Clarksburg.....WHAK
Morgantown...WHD

Wisconsin
Beloit.....WKAW
Kenosha.....WAOR
La Crosse.....WABN
Madison.....WGAY
WHA
Milwaukee.....WAAK
WCAY
WHAD
WIAO
Neenah.....WIAJ
St. Croix Falls..WRAL
Superior.....WFAC
Waupaca.....WPAH

Wyoming
Casper.....KFDF
Douglas.....KFEV
Laramie.....KFBU

CANADIAN STATIONS

Alberta
Calgary.....CFAC
CFCN
CHBC
CHCQ
CJCY
Edmonton.....CHCC
CJCA

British Columbia
Courtenay.....CFVC
Nelson.....CJCB
Vancouver.....CFCB
CFYC
CHCA
CHOC
CJCE
CKCD

Manitoba
Winnipeg.....CFCD
CHCF
CJCG
CJNC
CKCB
CKZC

New Brunswick
St. John.....CJCI
CKCR

Nova Scotia
Halifax.....CFCE
CHAC
CJCS

Ontario
Fort Frances...CFPC
Hamilton.....CHIC
CKOC
Iroquois Falls..CFCH
Kitchener.....CJCF
London.....CFCX
CHCS
CJGC
CKQC
Ottawa.....CHXC
Timmins.....CFBC
Toronto.....CFCA
CFTC
CHCB
CHCZ
CHFC
CHVC
CJCD
CJCH
CJCN
CJSC
CKCE
CKCZ
CKKC
Walkerville....CFCI

Quebec
Montreal.....CFCF
CFUC
CFZC
CHCX
CHYC
CJBC
CKAC
CKCS
Quebec.....CFCJ

Saskatchewan
Regina.....CKCK

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LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION ACCORDING TO THE INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

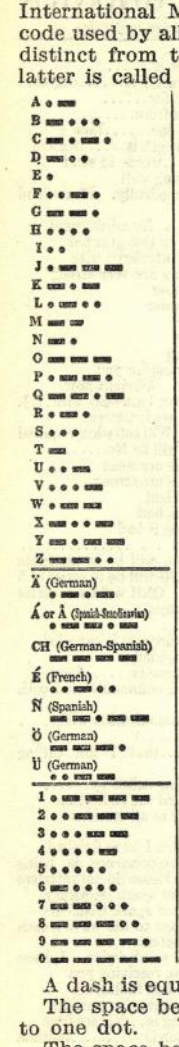
	Question	Answer or Notice
QRA	What ship or coast station is that?	This is.....
QRB	What is your distance?.....	My distance is.....
QRC	What is your true bearing?.....	My true bearing is.....degrees
QRD	Where are you bound for?.....	I am bound for.....
QRF	Where are you bound from?.....	I am bound from.....
QRG	What line do you belong to?.....	I belong to the.....Line
QRH	What is your wave length?.....	My wave length is.....meters
QRJ	How many words have you to send?	I have.....words to send
QRK	How do you receive me?.....	I am receiving well
QRL	Are you receiving badly? Shall I send 20?..... . . . — . . for adjustment.	I am receiving badly. Please send 20? . . . — . . for adjustment
QRLL	Request permission to test..min's	Permission to test granted
QRM	Are you being interfered with?...	I am being interfered with
QRN	Are the atmospherics strong?.....	Atmospherics are very strong
QRO	Shall I increase power?.....	Increase power
QRP	Shall I decrase power?.....	Decrease power
QRQ	Shall I send faster?.....	Send faster
QRS	Shall I send slower?.....	Send slower
QRT	Shall I stop sending?.....	Stop sending
QRU	Have you anything for me?.....	I have nothing for you
QRV	Are you ready?.....	I am ready. All right now
QRW	Are you busy?.....	I am busy (or: I am busy with...). Please do not interfere
QRX	Shall I stand by?.....	Stand by. Will call when required
QRY	When will be my turn?.....	Your turn will be No.....
QRZ	Are my signals weak?.....	Your signals are weak
QSA	Are my signals strong?.....	Your signals are strong
QSB	Is my tone bad?..... Is my spark bad?.....	The tone is bad The spark is bad
QSC	Is my spacing bad?.....	Your spacing is bad
QSD	What is your time?.....	My time is.
QSF	Is transmission to be in alternate order or in series?..... . . .	Transmission will be in alternate order. QSG will be in series of 5 messages. QSH will be in series of 10 messages
QSJ	What rate shall I collect for.....?	Collect.....
QSK	Is the last radiogram canceled?...	The last radiogram is canceled
QSL	Did you get my receipt?.....	Please acknowledge
QSM	What is your true course?.....	My true course is.....degrees
QSN	Are you in communication with land?.....	I am not in communication with land
QSO	Are you in communication with any ship or station (or: with...)?	I am in communication with..... (through.....)
QSP	Shall I inform.....that you are calling him?.....	Inform.....that I am calling him
QSQ	Is.. . .calling me?.....	You are being called by.....
QSR	Will you forward the radiogram?..	I will forward the radiogram
QST	Have you received the general call?	General call to all stations
QSU	Please call me when you have finished (or: at..o'clock).....	Will call when I have finished
*QSV	Is public correspondence being handled?.....	Public correspondence is being handled. Please do not interfere
QSW	Shall I increase spark frequency?	Increase your spark frequency
QSX	Shall I decrease spark frequency?	Decrease your spark frequency
QSY	Shall I send on a wave length of meters?.....	Let us change to the wave length of.....meters
QSZ		Send each word twice. I have difficulty in receiving you
QTA		Repeat the last radiogram
QTC	Have you anything to transmit?	I have something to transmit
QTE	What is my true bearing?	Your bearing is..degrees from...
QTF	What is my position?	Your position is.....latitude longitude

*Public correspondence is any radio work, official or private, handled on commercial wave lengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

INTERNATIONAL MORSE CODE

For the convenience of those who may desire to master the reading of radio telegraph messages the International Morse Code is here given. This is the code used by all radio telegraph stations and is entirely distinct from that used on the wire telegraph. The latter is called the American Morse Code.



Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Attention call to precede every transmission	— • — • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — — • • — — —
Question (please repeat after)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede all position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

A dash is equal in length to three dots.

The space between parts of the same letter is equal to one dot.

The space between two letters is equal in length to three dots.

The space between two words is equal in length to five dots.

CHARACTERISTICS OF RECEIVING AND POWER TUBES

The following table and the accompanying diagrams will be of great use in the selection of electron tubes and in their proper connection in receiving circuits when used as detectors and when used as amplifiers.

Receiving Tubes

Type	Filament		Plate		Amplification Factor	Output Resistance Ohms	Mutual Conductance Micromhos
	Volts "A"	Amperes	Volts "B"	Amperes			
*UV-199	3.0	0.06	40	0.001	6		
UV-200	5.0	1.0	20	0.001			
UV-201	5.0	1.0	40	0.001	6	20,000	300
UV-201A	5.0	0.25	40	0.0012	6.8	16,000	425
*WD-11	1.1	0.25	45	0.0005	6	20,000	300
WD-12	1.1	0.25	45	0.0005	6	20,000	300
*French	3.8	0.70	40		7	30,000	230
DV-6A	2.7	0.3	22-45		6.5	25,000	260
*215A, N	1.1	0.25	45	0.0006	6.5	25,000	260
216A	6	1.0	120	0.008	6	6,000	1000
VT1, 203B	2.5	1.1	30	0.001	7.5	15,000	430
†*VT2, 205B	7	1.35	350	0.04	7	4,000	1750

Power Tubes

Type	Filament		Plate		Amplification Factor	Output Watts
	Volts "A"	Amperes	Volts "B"	Amperes		
UV-202	7.5	2.35	350	0.050	7.5	5
UV-203	10.0	6.50	1000	0.150	15.0	50
UV-203A	10.0	3.25	1000	0.125	25.	50
UV-204	11.0	14.75	2000	0.250	20.	250
UV-204A	11.0	3.85	2000	0.200	25.	250
UV-206	11.0	14.75	10000	0.125	250.	1000
UV-207	22.0	52.00	15000	1.800	40.	20000
UV-208	22.0	24.50	15000	0.450	300.	5000

*Special base. All other receiving tubes in this list fit the standard base.

†May be used also as a transmitting tube.

Most of the information in the above table is taken from material supplied by the manufacturers of the tubes. While individual tubes differ somewhat in their characteristics, the figures here given are believed to be fairly typical of tubes of these types.

The mutual conductance of an electron tube is the amplification factor divided by the output resistance. It is a better criterion of the effectiveness of the tube than either of its constituent factors alone.

Most of the receiving tubes now on the market may be used either as amplifiers or as detectors. The return connection from the grid circuit to the filament battery should be different in the two cases. When used as a detector, the grid circuit should be connected to the positive end of the filament, as shown in Fig. 1. When used as an amplifier, the grid circuit should be connected to the negative terminal of the filament battery with

the filament rheostat connected between this point and the negative terminal of the filament, as shown in Fig. 2.

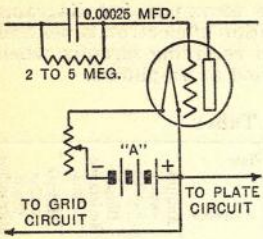


FIG. 1

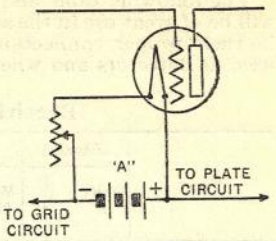


FIG. 2

If a higher voltage is used in the plate circuit of an amplifier tube than that given in column 4 of the above table, it is desirable to use an additional voltage or "C" battery in the grid circuit. About one volt of "C" battery should be used for each ten or fifteen volts increase in "B" battery above that given. Not more than 100 volts "B" battery nor 6 volts "C" battery should ordinarily be used. The "C" battery (sometimes called the grid bias battery) should have its negative terminal connected to the grid circuit and its positive terminal connected to the negative terminal of the filament "A" battery, as shown in Fig. 3. If a potentiometer is used as a method of controlling this grid bias, the connections should be made as shown in Fig. 4.

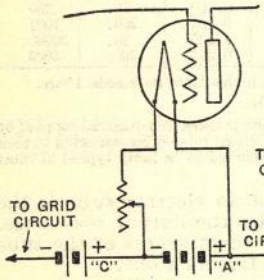


FIG. 3

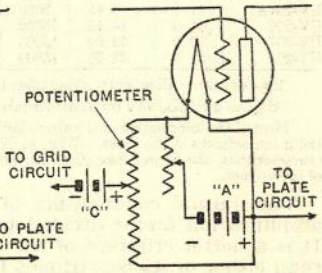


FIG. 4

Sometimes the application of an excessive filament or plate voltage causes a tube to become inoperative without actually burning out the filament. It can in some cases be restored by lighting the filament at the rated voltage for ten to twenty minutes with the plate or "B" battery entirely disconnected.

CONVERSION TABLE
Kilocycles to Meters

In line with the recommendation of the recent Radio Conference, we will do all we can to make it easy for our readers to adopt the term kilocycles instead of wavelength. The following conversion table will be of use to this end. It is reversible; that is, for example, 50 kilocycles is 5996 meters and also 50 meters is 5996 kilocycles. The range of the table is easily extended by shifting the decimal point; for example, one cannot find 223 in the first column, but its equivalent is obtained by finding later in the table that 2330 kilocycles or meters is equivalent to 134.4 meters or kilocycles, from which 223 kilocyles or meters is equivalent to 1344 meters or kilocycles.

10...	29980	530...	565.7	1050...	285.5	1570...	191.0
20...	14990	540...	555.2	1060...	282.8	1580...	189.8
30...	9994	550...	545.1	1070...	280.2	1590...	188.6
40...	7496	560...	535.4	1080...	277.6	1600...	187.4
50...	5996	570...	526.0	1090...	275.1	1610...	186.2
60...	4997	580...	516.9	1100...	272.6	1620...	185.1
70...	4283	590...	508.2	1110...	270.1	1630...	183.9
80...	3748	600...	499.7	1120...	267.7	1640...	182.8
90...	3331	610...	491.5	1130...	265.3	1650...	181.7
100...	2998	620...	483.6	1140...	263.0	1660...	180.6
110...	2726	630...	475.9	1150...	260.7	1670...	179.5
120...	2499	640...	468.5	1160...	258.5	1680...	178.5
130...	2306	650...	461.3	1170...	256.3	1690...	177.4
140...	2142	660...	454.3	1180...	254.1	1700...	176.4
150...	1999	670...	447.5	1190...	252.0	1710...	175.3
160...	1874	680...	440.9	1200...	249.9	1720...	174.3
170...	1764	690...	434.5	1210...	247.8	1730...	173.3
180...	1666	700...	428.3	1220...	245.8	1740...	172.3
190...	1578	710...	422.3	1230...	243.8	1750...	171.3
200...	1499	720...	416.4	1240...	241.8	1760...	170.4
210...	1428	730...	410.7	1250...	239.9	1770...	169.4
220...	1363	740...	405.2	1260...	238.0	1780...	168.4
230...	1304	750...	399.8	1270...	236.1	1790...	167.5
240...	1249	760...	394.5	1280...	234.2	1800...	166.6
250...	1199	770...	389.4	1290...	232.4	1810...	165.6
260...	1153	780...	384.4	1300...	230.6	1820...	164.7
270...	1110	790...	379.5	1310...	228.9	1830...	163.8
280...	1071	800...	374.8	1320...	227.1	1840...	162.9
290...	1034	810...	370.2	1330...	225.4	1850...	162.1
300...	999.4	820...	365.6	1340...	223.7	1860...	161.2
310...	967.2	830...	361.2	1350...	222.1	1870...	160.3
320...	936.9	840...	356.9	1360...	220.4	1880...	159.5
330...	908.6	850...	352.7	1370...	218.8	1890...	158.6
340...	881.8	860...	348.6	1380...	217.3	1900...	157.8
350...	856.6	870...	344.6	1390...	215.7	1910...	157.0
360...	832.8	880...	340.7	1400...	214.2	1920...	156.2
370...	810.3	890...	336.9	1410...	212.6	1930...	155.3
380...	789.0	900...	333.1	1420...	211.1	1940...	154.5
390...	768.8	910...	329.5	1430...	209.7	1950...	153.8
400...	749.6	920...	325.9	1440...	208.2	1960...	153.0
410...	731.3	930...	322.4	1450...	206.8	1970...	152.2
420...	713.9	940...	319.0	1460...	205.4	1980...	151.4
430...	697.3	950...	315.6	1470...	204.0	1990...	150.7
440...	681.4	960...	312.3	1480...	202.6	2000...	149.9
450...	666.3	970...	309.1	1490...	201.2	2010...	149.2
460...	651.8	980...	305.9	1500...	199.9	2020...	148.4
470...	637.9	990...	302.8	1510...	198.6	2030...	147.7
480...	624.6	1000...	299.8	1520...	197.2	2040...	147.0
490...	611.9	1010...	296.9	1530...	196.0	2050...	146.3
500...	599.6	1020...	293.9	1540...	194.7	2060...	145.5
510...	587.9	1030...	291.1	1550...	193.4	2070...	144.8
520...	576.6	1040...	288.3	1560...	192.2	2080...	144.1

2090...	143.5	2820...	106.3	4100...	73.13	6400...	46.85
2100...	142.8	2830...	105.9	4120...	72.77	6450...	46.48
2110...	142.1	2840...	105.6	4140...	72.42	6500...	46.13
2120...	141.4	2850...	105.2	4160...	72.07	6550...	45.77
2130...	140.8	2860...	104.8	4180...	71.73	6600...	45.43
2140...	140.1	2870...	104.5	4200...	71.39	6650...	45.09
2150...	139.5	2880...	104.1	4220...	71.05	6700...	44.75
2160...	138.8	2890...	103.7	4240...	70.71	6750...	44.42
2170...	138.1	2900...	103.4	4260...	70.38	6800...	55.09
2180...	137.5	2910...	103.0	4280...	70.05	6850...	43.77
2190...	136.9	2920...	102.7	4300...	69.73	6900...	43.45
2200...	136.3	2930...	102.3	4320...	69.40	6950...	43.14
2210...	135.7	2940...	102.0	4340...	69.08	7000...	42.83
2220...	135.1	2950...	101.6	4360...	68.77	7050...	42.53
2230...	134.4	2960...	101.3	4380...	68.45	7100...	42.23
2240...	133.8	2970...	100.9	4400...	68.14	7150...	41.93
2250...	133.3	2980...	100.6	4420...	67.83	7200...	41.64
2260...	132.7	2990...	100.3	4440...	67.53	7250...	41.35
2270...	132.1	3000...	99.94	4460...	67.22	7300...	41.07
2280...	131.5	3020...	99.28	4480...	66.91	7350...	40.79
2290...	130.9	3040...	98.62	4500...	66.63	7400...	40.52
2300...	130.4	3060...	97.98	4520...	66.33	7450...	40.24
2310...	129.8	3080...	97.34	4540...	66.04	7500...	39.98
2320...	129.2	3100...	96.72	4560...	65.75	7550...	39.71
2330...	128.7	3120...	96.10	4580...	65.46	7600...	39.45
2340...	128.1	3140...	95.48	4600...	65.18	7650...	39.19
2350...	127.6	3160...	94.88	4620...	64.90	7700...	38.94
2360...	127.0	3180...	94.28	4640...	64.62	7750...	38.69
2370...	126.5	3200...	93.69	4660...	64.34	7800...	38.44
2380...	126.0	3220...	93.11	4680...	64.06	7850...	38.19
2390...	125.4	3240...	92.54	4700...	63.79	7900...	37.95
2400...	124.9	3260...	91.97	4720...	63.52	7950...	37.71
2410...	124.4	3280...	91.41	4740...	63.25	8000...	37.48
2420...	123.9	3300...	90.86	4760...	62.99	8050...	37.25
2430...	123.4	3320...	90.31	4780...	62.72	8100...	37.02
2440...	122.9	3340...	89.77	4800...	62.46	8150...	36.79
2450...	122.4	3360...	89.23	4820...	62.20	8200...	36.56
2460...	121.9	3380...	88.70	4840...	61.95	8250...	36.34
2470...	121.4	3400...	88.18	4860...	61.69	8300...	36.12
2480...	120.9	3420...	87.67	4880...	61.44	8350...	35.91
2490...	120.4	3440...	87.16	4900...	61.19	8400...	35.69
2500...	119.9	3460...	86.65	4920...	60.94	8450...	35.48
2510...	119.5	3480...	86.16	4940...	60.69	8500...	35.27
2520...	119.0	3500...	85.66	4960...	60.45	8550...	35.07
2530...	118.5	3520...	85.18	4980...	60.20	8600...	34.86
2540...	118.0	3540...	84.70	5000...	59.96	8650...	34.66
2550...	117.6	3560...	84.22	5050...	59.37	8700...	34.46
2560...	117.1	3580...	83.75	5100...	58.79	8750...	34.27
2570...	116.7	3600...	83.28	5150...	58.22	8800...	34.07
2580...	116.2	3620...	82.82	5200...	57.66	8850...	33.88
2590...	115.8	3640...	82.37	5250...	57.11	8900...	33.69
2600...	115.3	3660...	81.92	5300...	56.75	8950...	33.50
2610...	114.9	3680...	81.47	5350...	56.04	9000...	33.31
2620...	114.4	3700...	81.03	5400...	55.52	9050...	33.13
2630...	114.0	3720...	80.60	5450...	55.01	9100...	32.95
2640...	113.6	3740...	80.17	5500...	54.51	9150...	32.77
2650...	113.1	3760...	79.74	5550...	54.02	9200...	32.59
2660...	112.7	3780...	79.32	5600...	53.54	9250...	32.41
2670...	112.3	3800...	78.90	5650...	53.07	9300...	32.24
2680...	111.9	3820...	78.49	5700...	52.60	9350...	32.07
2690...	111.5	3840...	78.08	5750...	52.14	9400...	31.90
2700...	111.0	3860...	77.67	5800...	51.69	9450...	31.73
2710...	110.6	3880...	77.27	5850...	51.25	9500...	31.56
2720...	110.2	3900...	76.88	5900...	50.82	9550...	31.39
2730...	109.8	3920...	76.49	5950...	50.39	9600...	31.23
2740...	109.4	3940...	76.10	6000...	49.97	9650...	31.07
2750...	109.0	3960...	75.71	6050...	49.56	9700...	30.91
2760...	108.6	3980...	75.33	6100...	49.15	9750...	30.75
2770...	108.2	4000...	74.96	6150...	48.75	9800...	30.59
2780...	107.8	4020...	74.58	6200...	48.36	9850...	30.44
2790...	107.5	4040...	74.21	6250...	47.97	9900...	30.28
2800...	107.1	4060...	73.85	6300...	47.59	9950...	30.13
2810...	106.7	4080...	73.49	6350...	47.22	10000...	29.98

LEFAX, PHILADELPHIA, PA. ORIGINAL COPR. 1910 BY J. C. PARKER

RADIO LOG

Call Letter	*	LOCATION	Distance Miles	Date	Time	REMARKS (Tuning, weather, special feature, quality, etc.)
WOO		Phila., Pa	14	3/12/23	7.50	Band selections. Organ
KYW	*	Chicago, Ill.	700	"	10.15	†-18½, ‡=4, O-14, ●=85 Clear, cool. dance music. good
WWJ	*	Detroit, Mich.	475	"	10.35	†=16, ‡=4, O=12½, ●=80 " " vocal faint
WGY		Schenectady, N.Y.	250	"	10.40	Banquet of Artisans " " loud
WGM		Atlanta, Ga.	650	"	11.20	Quartette southern songs " " variable
WIP		Phila., Pa	14	3/13/23	7.45	After-dinner tricks. Vocal selections. Dance music
WWJ		Detroit, Mich.	475	"	10.15	Speeches, songs, orchestra selections. Cloudy. Fair
WJZ		Newark, N.J.	75	"	10.30	Songs and dance music. Good but not loud.
WFI		Phila., Pa.	14	3/14/23	8.05	Orchestra-dance music. Organ recital.
WJAX		Cleveland, Ohio	350	"	10.35	Talk on insecticides. Dance music. Clear, cold. loud, good
WOR		Newark, N.J.	75	"	10.50	Radio hints
WDAF	*	Kansas City, Mo.	1050	"	11.25	†=17, ‡=4, O=16½, ●=80. Dance music. Good
KYW		Chicago, Ill.	700	"	11.40	Violin selections. Distinct but not loud
WOO		Phila., Pa.	14	3/15/23	7.50	Vocal and instrumental. Organ selections
WHAZ	*	Troy, N.Y.	220	"	8.55	Agricultural lecture †=16½, ‡=4, O=10, ●=70
KDKA		Pittsburgh, Pa	300	"	9.30	Piano selections. Cloudy-cold. Fading.

MARCH 12–18 EVENINGS

LEFAX FILING INDEX

*First time station was heard †=Ant. Cond. ‡=Ind. Sw. O=Dickler ●=Potentiometer = ×=

Hints on Use of Radio Log

Put asterisk in column 2 only the first time you hear a certain station. This will allow you to quickly find the total number of different stations heard on your set by simply counting the asterisks.

The symbols at bottom of sheet are to be assigned to your various tuning adjustments. This will save space in the Remarks column as shown. Six symbols are provided. If you do not need all of them for dial settings, use the balance for indications of weather conditions, quality, etc.

Dial settings need be recorded but once. They can be quickly found by glancing over the stations marked with an asterisk. It is wise, however, to check these settings occasionally as a slight change may be made in the wave length of the transmitter.

Indicate change of date by short dashes as shown, or leave a blank line between one day's entries and another's.

When additions or improvements are made in your receiving set, leave a blank line or two and give details. in Remarks column. This will show the reasons for the improved results recorded subsequently. Even slight improvements, like a new B battery should be so recorded.

If your equipment allows switching over from antenna to loop indicate type of aerial used in Remarks column.

The regular Radio Log is ruled on both sides and will allow 32 entries.

Price 25c (in U. S. A.) for pack of 40 sheets.

Order from your stationer or

LEFAX, Inc.

9th & Sansom Streets - Philadelphia, Pa.

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ADDRESSES

LEFAX FILING INDEX

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Name.....

Address.....

.....

Phone.....

Name.....

Address.....

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Phone.....

Name.....

Address.....

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Phone.....

Name.....

Address.....

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Phone.....

Name.....

Address.....

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Phone.....

Name.....

Address.....

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Phone.....

Name.....

Address.....

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Phone.....

MADE IN U.S.A.

LEFAX, PHILADELPHIA, PA.

Name.....

Address.....

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Phone.....

Name.....

Address.....

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Phone.....

Name.....

Address.....

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Phone.....

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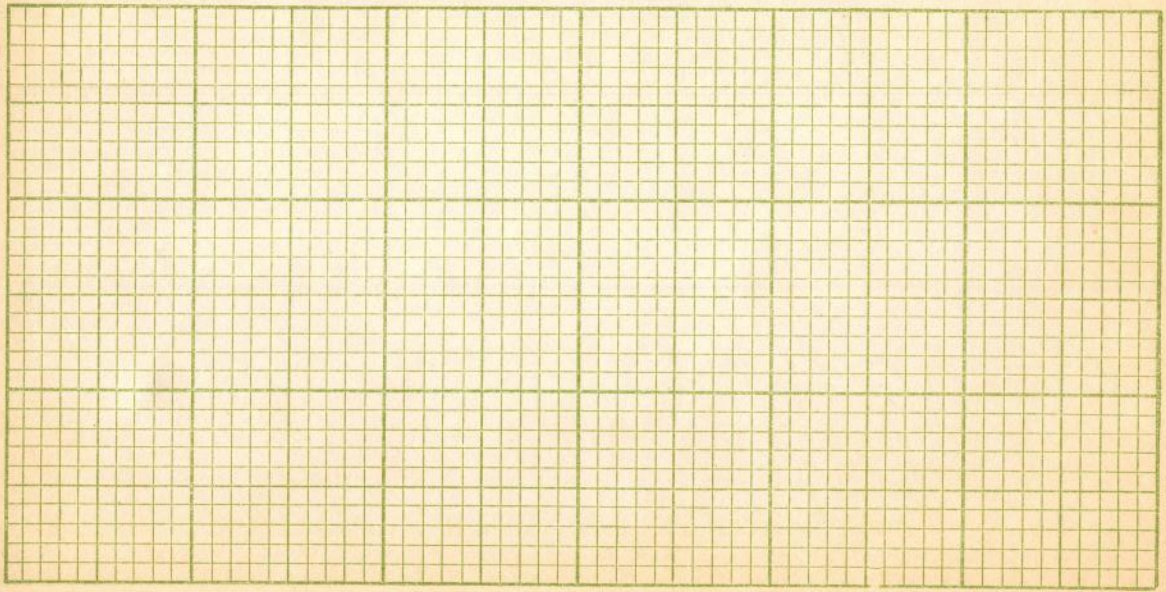
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